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THE WORKINGS OF
PLANETARY HOOPS

Black Holes at the Hearts of All Galaxies

Space Birds Tempt the Sky Trackers

LX50

Advanced technology at the most affordable prices *ever.*

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

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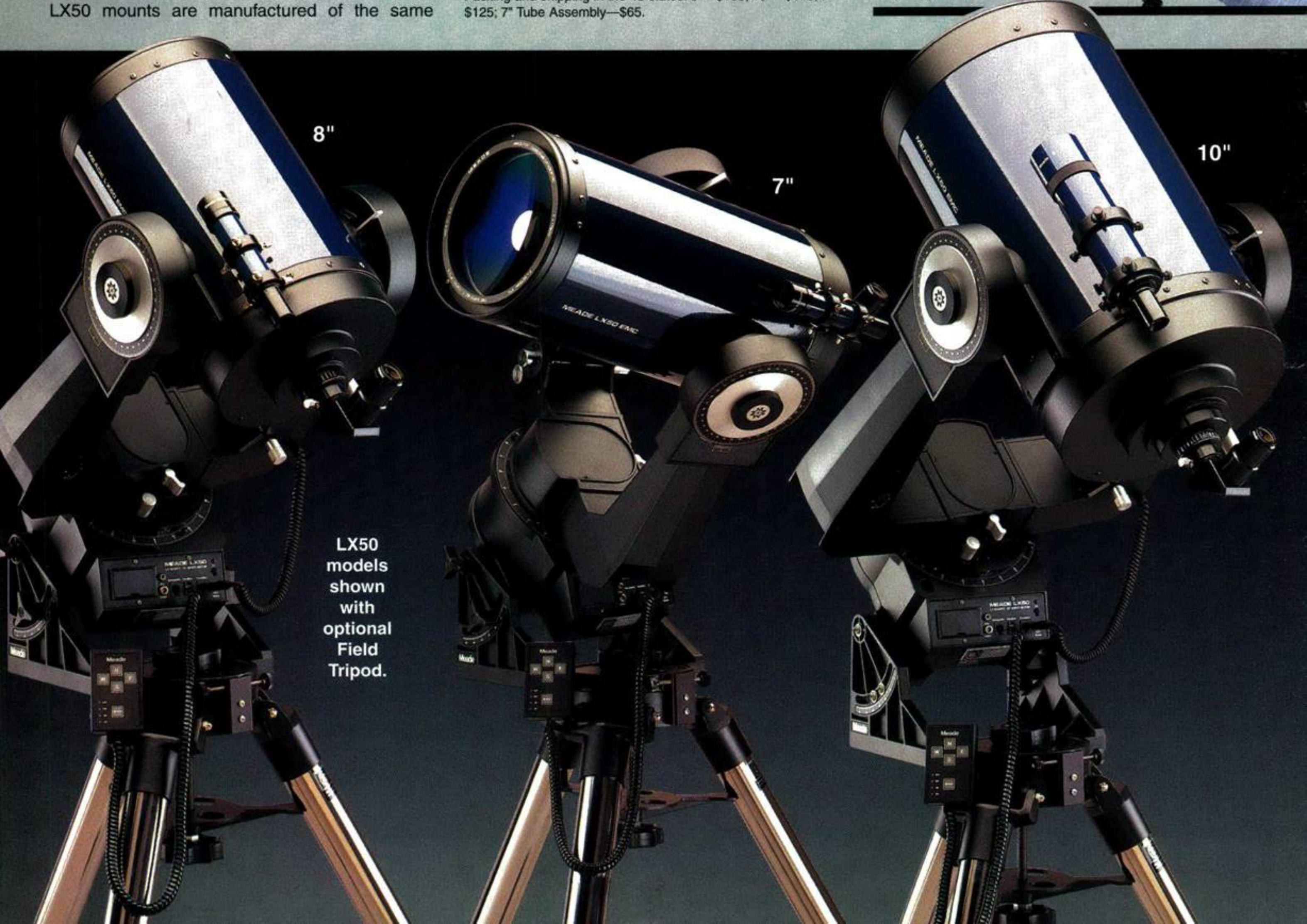


LX50 models shown with optional Field Tripod.

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

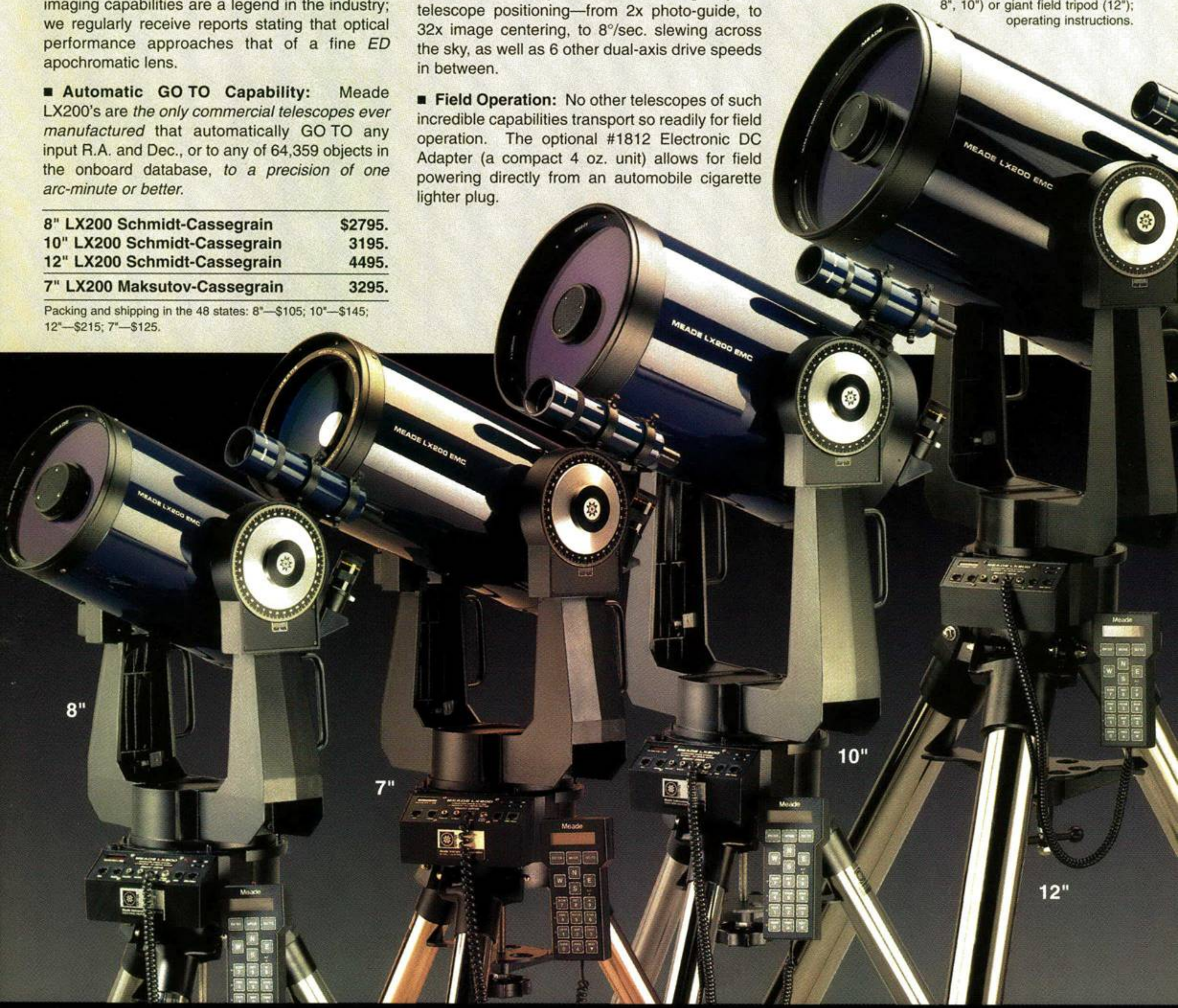
- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.



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COVER PHOTO: E. Karkoschka (Univ. of Arizona) and NASA

FEATURES

34 **Ask Astro**
We answer your questions about the sky and the universe.

40 **Eyes on the Universe**
Much of what we know about planets, stars, galaxies, and the cosmos stems from the contributions of these 25 landmark telescopes and observatories.

42 **To the Edge of Space and Time**
With gravity so strong it warps the very fabric of space-time, a black hole is nature at its most exotic. *Martin Rees.*

48 **A Beast in the Core**
Nearly every big galaxy seems to harbor a huge black hole — a fossil, perhaps, of an earlier quasar phase. *Marcia Bartusiak.*

COVER
54 **Ruling the Rings**
Saturn may have the prettiest, but all the gas giants have rings. Stark differences among these magnificent systems clue us in on how they form and evolve. *Neil F. Comins.*

58 **Planet Hunters**
Astronomers Geoff Marcy and Paul Butler have discovered more planets than anyone else. *Sally Stephens.*

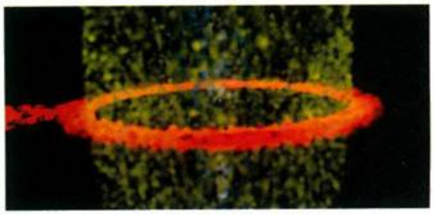
82 **Seeing Red**
Far from the black-and-white canvas it appears to the naked eye, the sky glows with glorious pastel shades. *Bob Berman.*

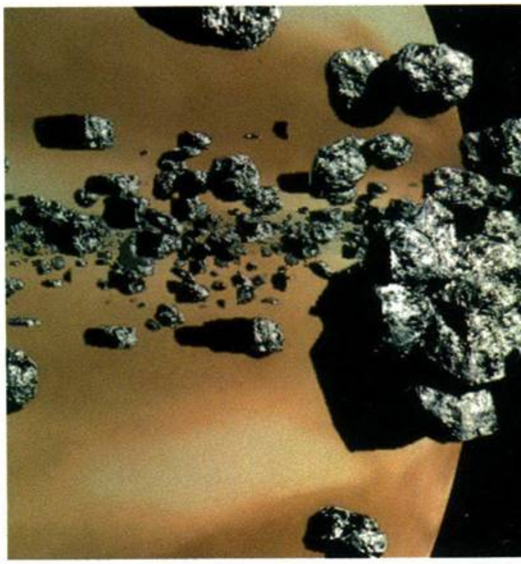
90 **It's a Bird … It's a Plane … It's a Satellite**
On a good night you can spot a dozen or more satellites, if you know where and when to look. *Nancy L. Hendrickson.*

94 **Strike a Pose**
Celestron's new 9¼-inch Schmidt-Cassegrain telescope boasts a bigger mirror, smarter tracking, and a sturdier mount than the standard 8-inch SCT. *John Shibley.*

54 Unveiling Rings
NASA/JPL

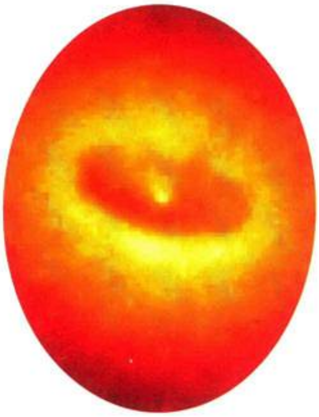
42 To the Edge of Space and Time
NASA





90 Space Birds Tempt the Sky Trackers
Brian Webb

DEPARTMENTS



48 Black Holes Holland Ford (Johns Hopkins Univ.), et al., and NASA

6 Behind the Scenes
- That Asteroid Caper

16 Talking Back

22 AstroNews
- Unmasking the Face on Mars
- Astronomers Smash Distance Record
- Hubble Catches the Youngster Stingray
- Amateur Studies Starburst
- Blue Dwarf Galaxies Not Infants
- New Dust Ring for Jupiter
- Dinosaur Killer Sheds Light on Mars

68 Sky Show
- The gas giant Neptune glows at its brightest this month, but the star of these warm summer nights is Saturn and its shadowed rings. *Martin Ratcliffe and Alister Ling.*

100 Star Stuff

Products
- "From the Earth to the Moon" Telescope Line
- CountDown Wall Clock
- Zenit 122M Astrophotography Kit
- Swarovski Optik Astronomical Eyepieces

Books
- Questioning the Millenniur A Rationalist's Guide to a Precisely Arbitrary Countdown
- Millennium Star Atlas

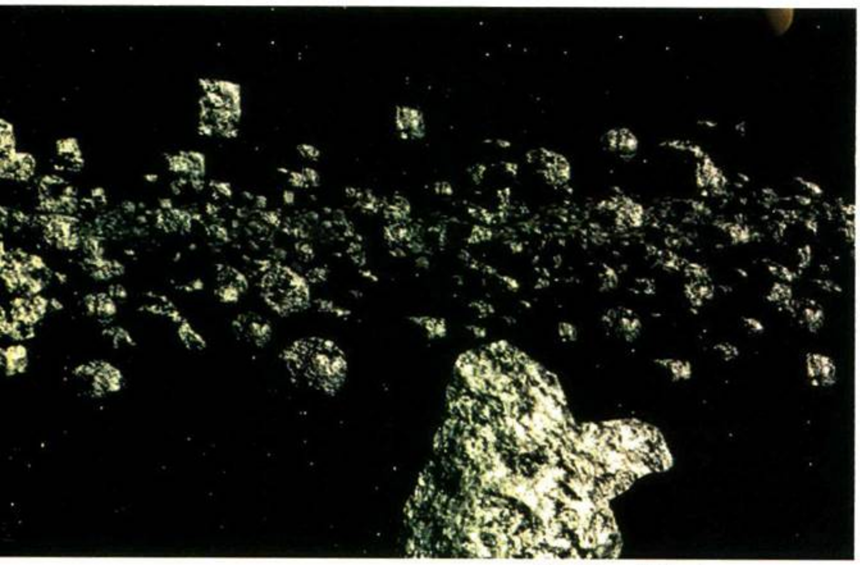
Bytes
- Astronomical Images
- Hale-Bopp Screen Savers

116 Looking Ahead

119 Advertiser Index

120 Hot Shots
- Moon Shadow

126 Ultimate Exposure



58 Planet Hunters John Whatmough

94 Strike a Pose

Astronomy: Rebecca Saliture

82 Seeing Red

Bill and Sally Fletcher

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

That Asteroid Caper

As of this writing, we are still getting mail asking if that much-talked-about asteroid will collide with Earth in 2028. Everyone agrees it will not. With observations from several years in hand, we now see that the comet's orbit will bring it no closer than 600,000 miles from us in 30 years. But, no doubt, some other comet or asteroid will draw near.

Today there are 113 Potentially Hazardous Objects (PHOs) listed at the website of the International Astronomical Union. What makes a comet or asteroid Potentially Hazardous is having an orbit that comes within 0.05 AU (or 5 million miles) of Earth's orbit and an absolute magnitude of 22 or brighter, suggesting a radius of 200 or more meters. The Minor Planet Center of the International Astronomical Union in Cambridge, Massachusetts, lists observations of these objects, hoping someone will verify their orbits.

Paramount Pictures

A powerful collision of Earth and a comet is the focus of the movie *Deep Impact*.

In December 1997, there were 108 such objects. One of them was asteroid 1997 XF11, the one that for 24 hours the whole world feared. The first calculations for the asteroid's orbit were based on few observations. A circular went out from the center's director Brian Marsden to professional comet and asteroid watchers suggesting that the orbit of the asteroid could come within 15,000 miles of Earth (a very close encounter) on October 26, 2028, and it asked for observing help. When additional observations were added two days later, the orbit was recalculated, and scientists found that we apparently will miss that object by some 600,000 miles.

A small debate is emerging among asteroid and comet hunters (and those who fund them) about how much information should be distributed on early observations — and to whom. Some researchers would like the major players to be notified discreetly of new observations. No more of those nasty circulars that could fall into the hands of hot-headed journalists and their overanxious readers. (The circulars, it turns out, are sent mostly to folks who are in the business. But some news-hungry publications are on the circular mailing list, and it was reporters for those who asked the questions that brought the potential calamity to the world's attention.) Brian Marsden is working to discourage attempts to control observational information, but the verdict is out on what will trickle down from the asteroid caper.

"The good news in all of this," says Brian, "is that NASA just announced it's doubling the amount of money it spends on asteroid searches — from $1.5 million a year to $3 million. Perhaps that decision is the result of the public interest in asteroid 1997 XF11, who knows?"

Some scientists worry that the whole affair was like crying wolf and people won't take such threats seriously if mistakes are made. We think this was a perfect lesson in how science works. Hypotheses are made, based on limited information — and then modified with testing.

Astronomy

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MEADE ETX

90mm Maksutov-Cassegrain

Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$595***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$595*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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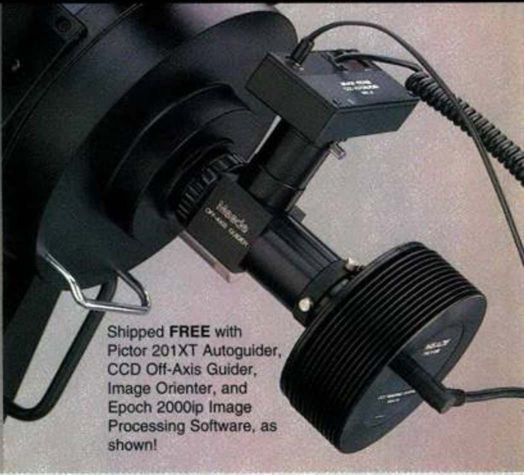

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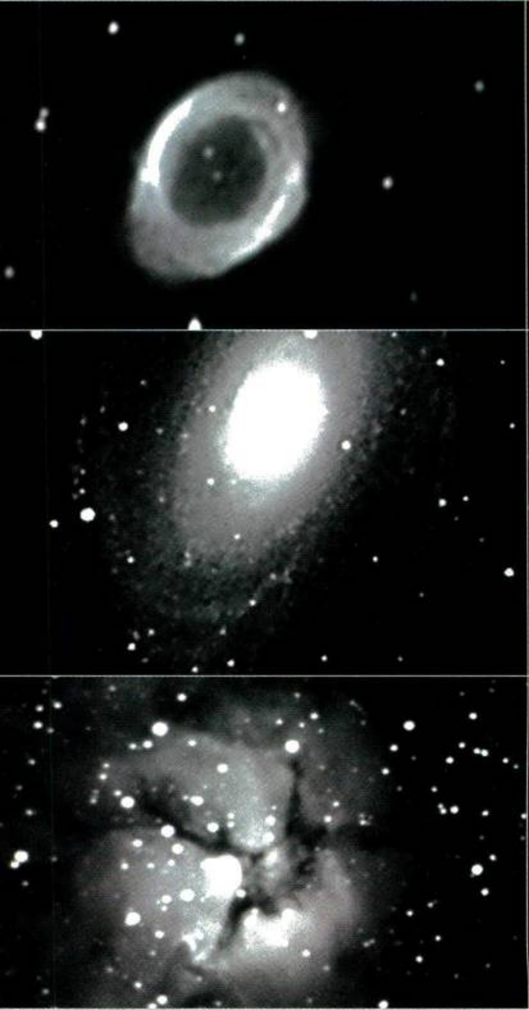
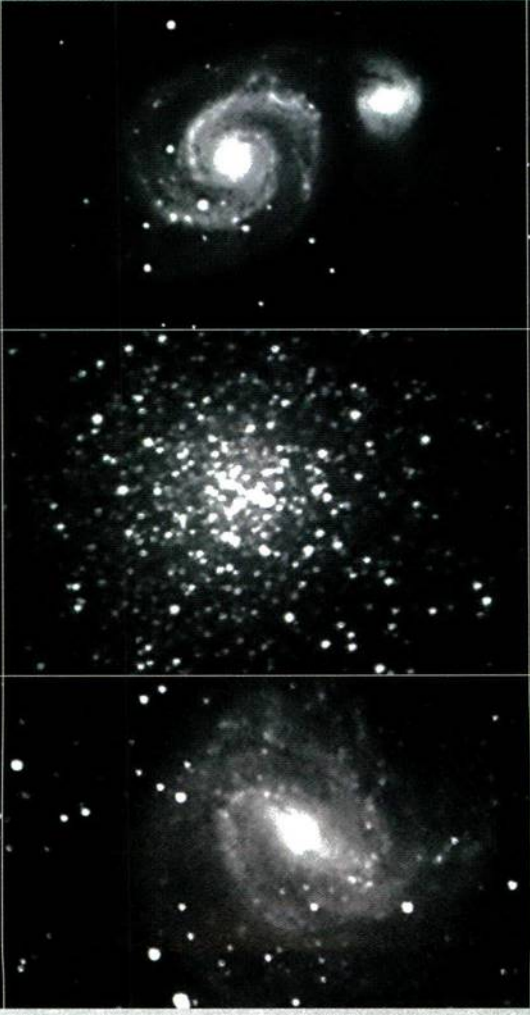
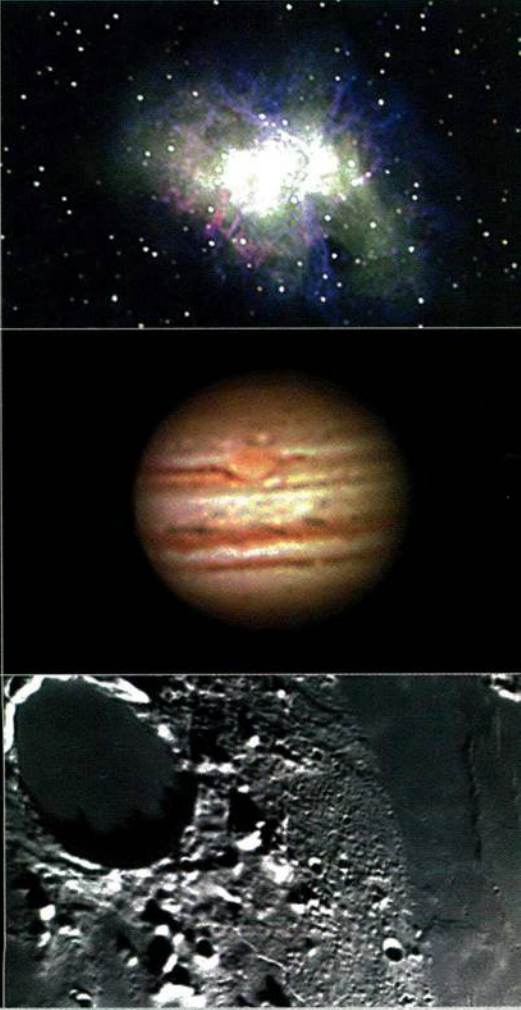
Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 100-page Meade General Catalog.***



Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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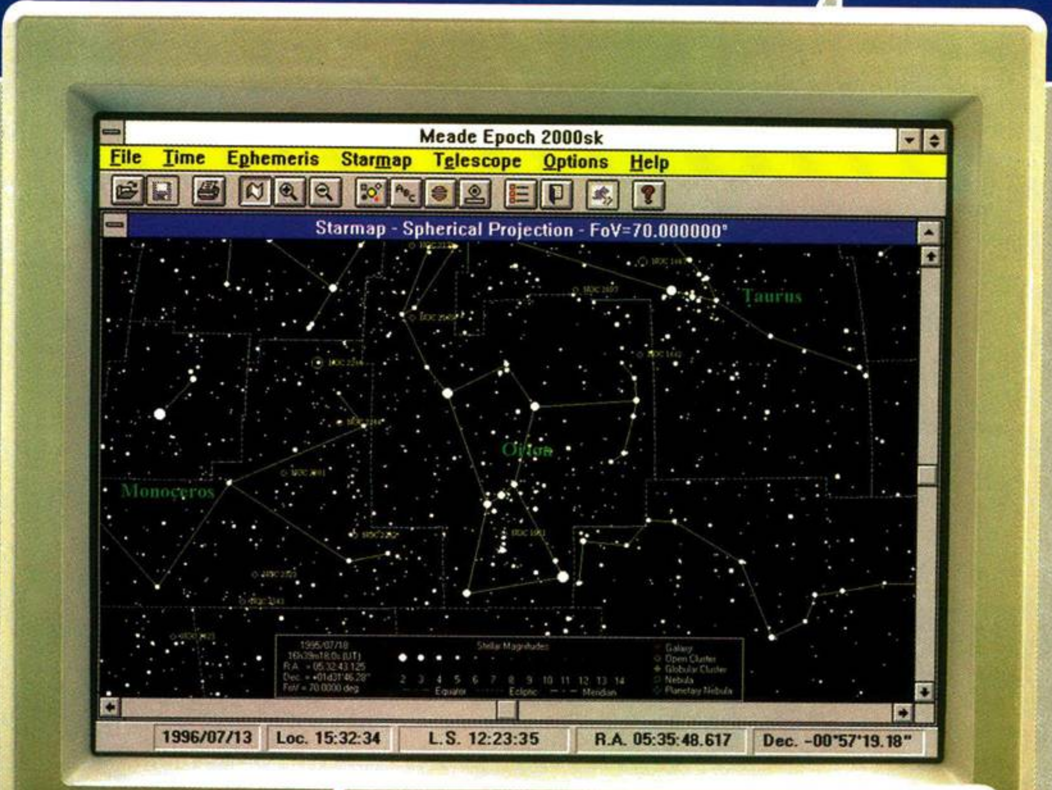

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Now you can use the most advanced, most precise sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** no longer is the Trapezium in Orion, for example, shown as a single point as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professsional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

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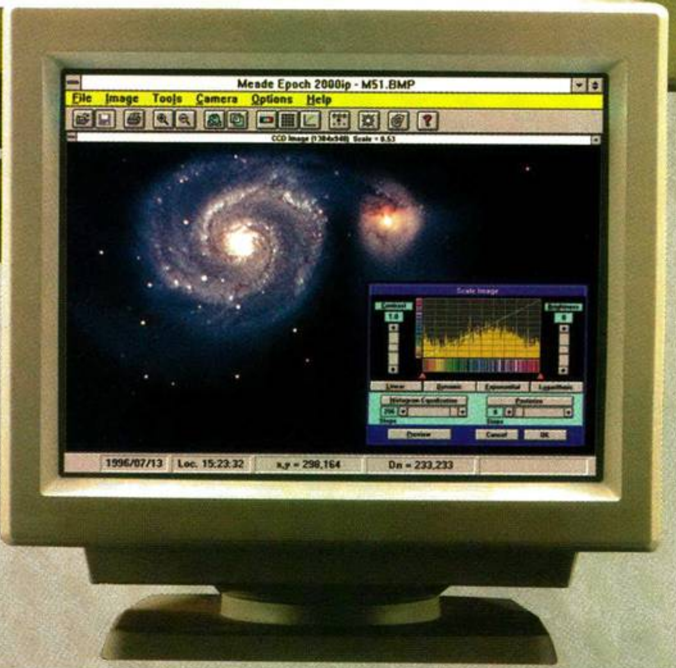

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

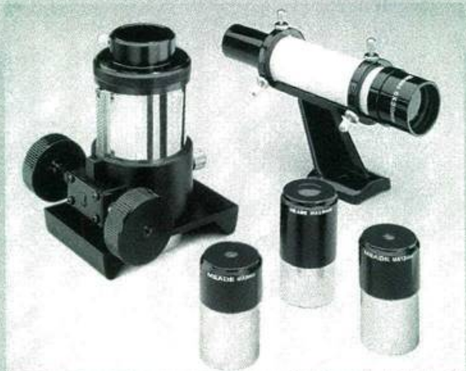
5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only $49.95!



Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- **1 - Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- **1 - Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- **3 - Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

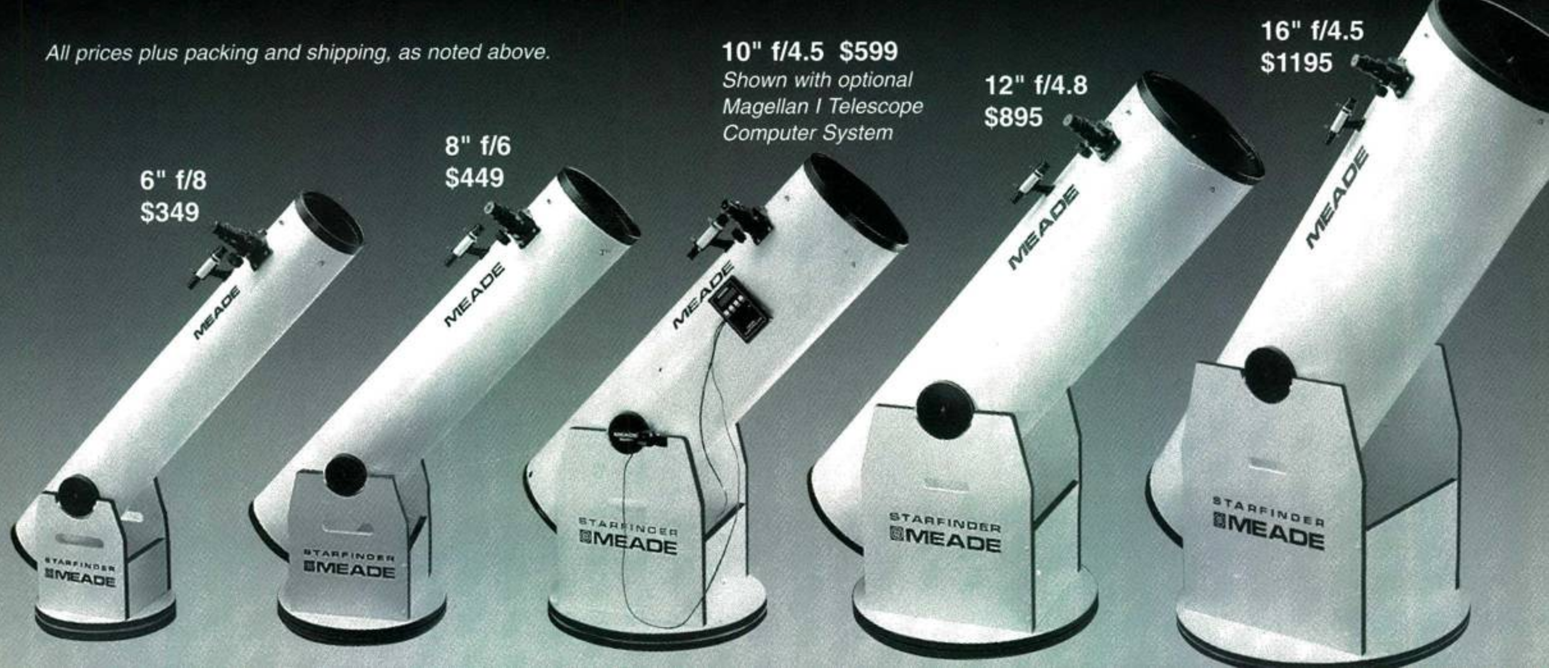
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

MEADE
ENTER
MODE
PREV
NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



All prices plus packing and shipping, as noted above.

6" f/8
$349

8" f/6
$449

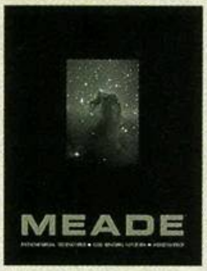
10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE
STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*



The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 100-page Meade General Catalog.

Write, call, or fax Meade Instruments for your free copy!

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
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POCONO MOUNTAIN OPTICS, Moscow, PA.
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RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
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Orders & Information: 416-783-4140.

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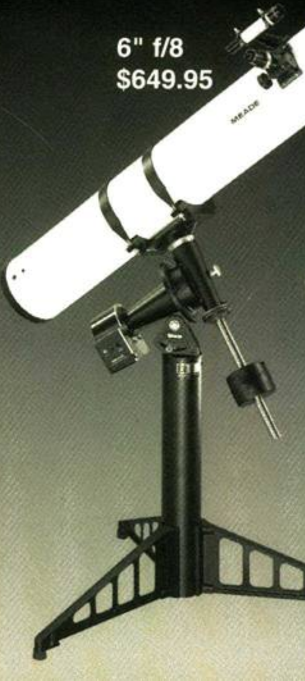
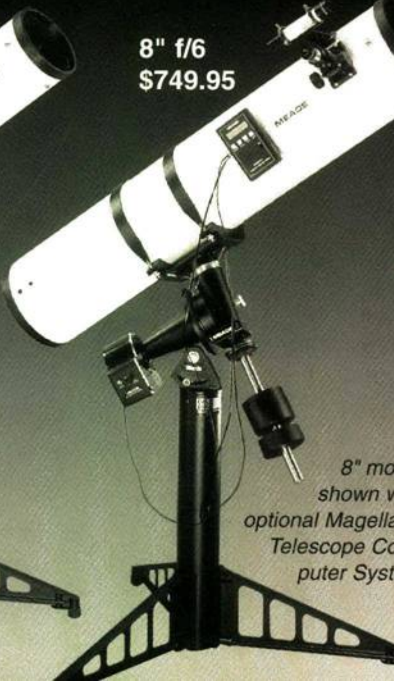
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***

6" f/8
$649.95

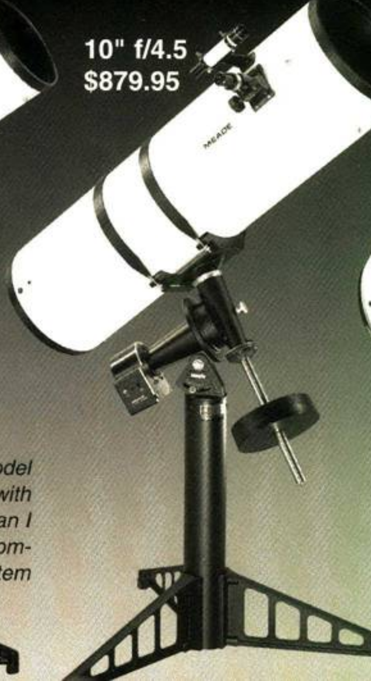


8" f/6
$749.95

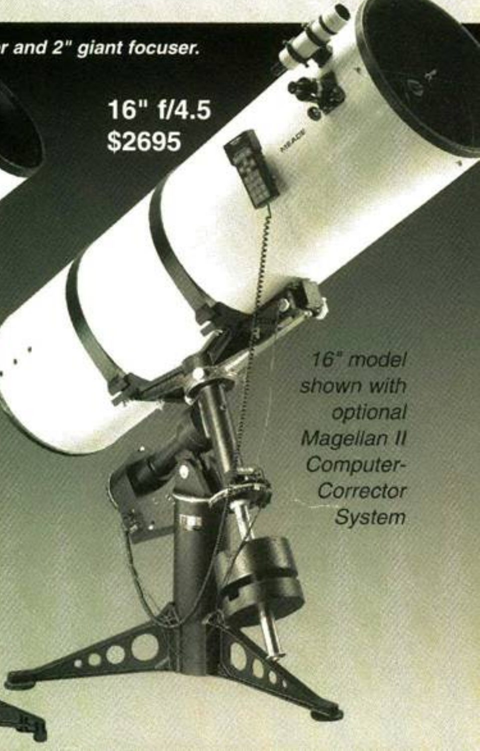


8" model shown with optional Magellan I Telescope Computer System

10" f/4.5
$879.95



16" f/4.5
$2695



16" model shown with optional Magellan II Computer-Corrector System

8" LX10

8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only $995!

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

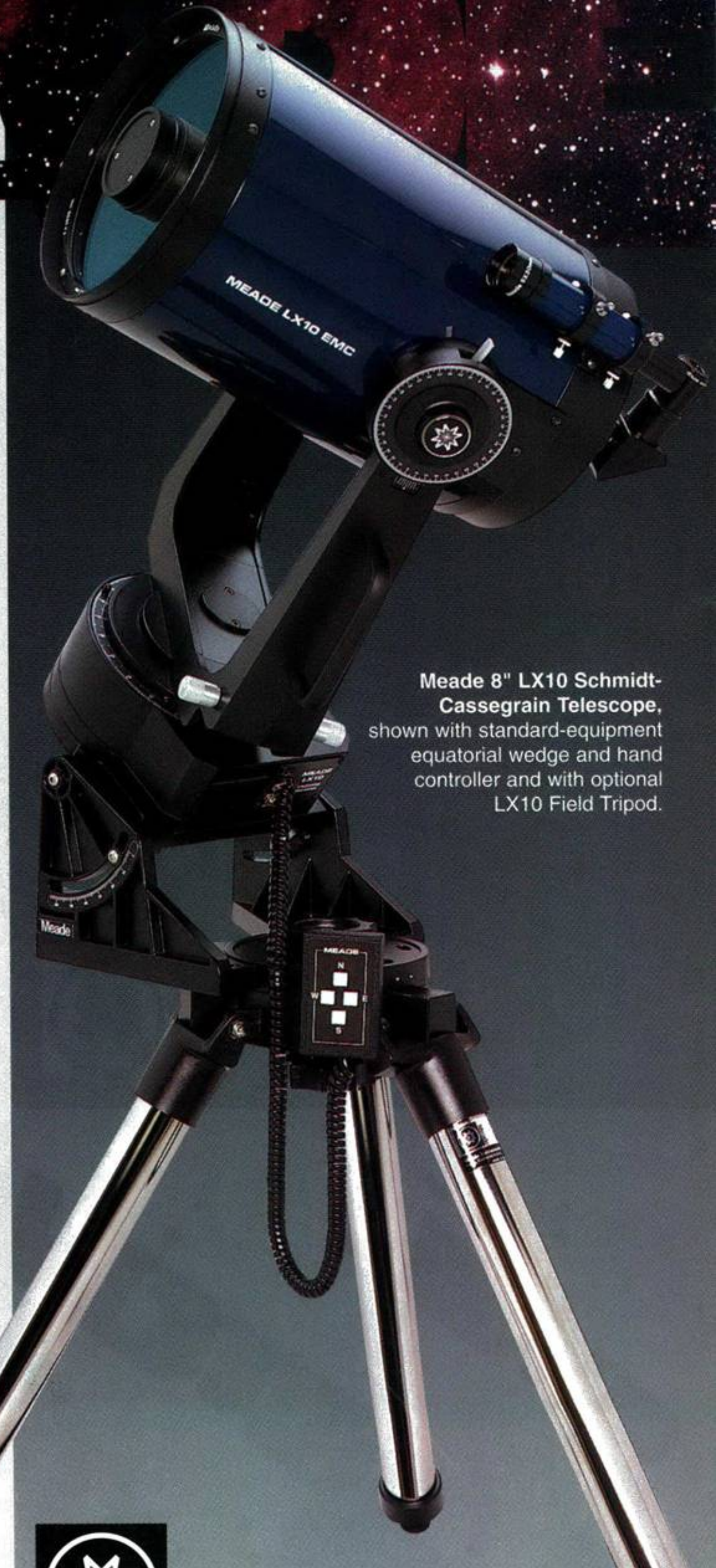
SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) a premium-grade Meade Series 4000 Super Plössl 26mm eyepiece (in place of the standard MA25mm eyepiece); and (c) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed—all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; and with Meade #544 8 x 50mm achromatic viewfinder and Series 4000 Super Plössl 26mm multi-coated eyepiece included in place of the 6 x 30mm viewfinder and MA25mm eyepiece of the LX10. **$1149.** (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	195.
Electric Declination Motor System for LX10	95.
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	375.

The 100-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers.
Prices shown are suggested U.S. mail-order prices.



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

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MEADE
EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45); **40mm** (44° field): **$79.95** (3.79)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#911B
#910B
#908B

#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

#911X
New!
#910X
#908X

Series 4000 Oxygen-III Filter—Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (3.45)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (3.85)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (3.94)

Series 4000 Zoom Eyepiece

The first zoom eyepiece—ever—to yield absolutely uncompromised resolution, color correction, and image brightness. Includes 8 elements, zooms from 7.7mm to 23.1mm with pinpoint imaging from edge to edge. Fully multicoated optics permit 99.8% light transmission at each air-to-glass surface. Apparent field 62° at 7.7mm; fold-down rubber eyecup; threaded for filters; 1.25".

$295. (6.28)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:
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Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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THE LARGEST-SELLING TELESCOPES IN THE WORLD

Meade Instruments is pleased to recommend the authorized Meade dealers on these pages for your telescope-buying requirements. Whether you're looking for a quality entry-level telescope at under-$200, a fully equipped professional instrument at over-$5000, or one of more than 2 dozen models in between, there's a Meade telescope that's right for your budget and applications.

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Full-line Meade. Optical expert on staff. Over 50 years' experience selling telescopes!
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818-762-4749

CALIFORNIA

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Astronomy Goes Hollywood

I loved Philip Plait's article on Hollywood astronomy ("Hollywood: A Full Moon in Every Plot," April 1998). Let me note, though, that it's not always the writer's fault when the science is bad in a movie. It's as likely to be the director or even someone lower on the totem pole, like the sound mixer or editor, who takes a script with valid science and screws it up.

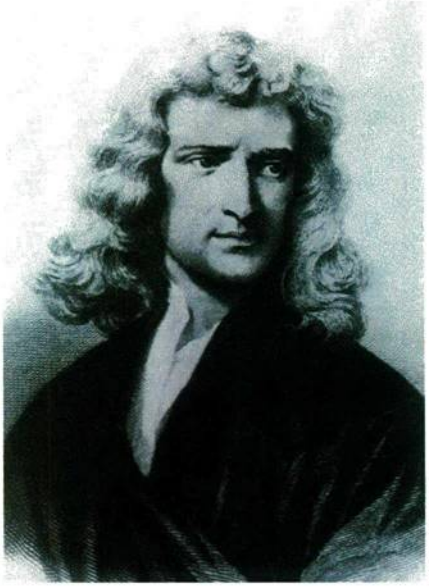
I'm a novelist and screenwriter with a degree in astronomy, but I might as well have studied home economics for all the scientific accuracy I can put into a movie. I wrote a science fiction movie for kids and by the time it was complete, it had a basic goof in science or engineering every few minutes (which makes it a valuable teaching tool — stop the movie every time there's a mistake and don't restart it until someone identifies the error). Toward the end of the movie, though, there's an explosion in space, and they actually followed the script and made it silent. I dropped my popcorn in amazement. — *Joe Haldeman, Gainesville, Florida*

Thank you for your long-overdue article on Hollywood's treatment of scientific accuracy. I would like to add a couple more to your list of gaffes. Philip Plait, the author, mentioned that lasers travel at light speed, meaning that a target would not even know it had been fired upon until it was hit. I'd like to add that lasers are also invisible when traveling through a non-reflective medium (such as space). Anyone who has used a laser pointer knows that you never see the beam in transit, only its reflection after striking the target.

Also, thank you for mentioning one of my all-time favorite movies, *2001: A Space Odyssey*. Nonetheless, for all of Mr. Kubrick's care, even he fell into one of Mr. Plait's traps: exterior views of Discovery show those pesky stars sliding by gracefully. — *Terry Burlison, Kent, Washington*

Was Newton Nuts?

Rosemary Sullivant's excellent article on the life of Isaac Newton ("When the Apple Falls," April 1998) would have been even better if it had included some comments on the persuasive argument of neurologist Harold L. Klawans in *Newton's Madness*, which suggests that his alchemical experiments accounted for his periodic mental problems. Newton spent a lot of time around heated mercury, even sleeping in the same room during some of his experiements. His episodes of pathological behavior appear to coincide with these experiments. Klawans details the understood neurological effects of prolonged exposure to mercury, which include the symptoms ascribed to Newton. — *Donald K. Henry, Mill Valley, Florida*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Slinging More Pond Scum

Regarding the Pond Scum Controversy ("Talking Back," April 1998) in reference to the February 1998 article by Mr. Kolb listing the items that had their genesis in the primordial soup, I would like to point out, in the interest of inter-species diplomacy, that pond scum is a colorful, globally dispersed, rich, effluvient life form that provides habitat and delectible nutrition to many. Mr. Gingrich, on the other hand, is merely a politician and of far less value to the survival of the species. Fairness is in the sensory organ of choice of the beholder. — *Paul Walsh, Redmond, Washington*

El Kabong

I'm sure that at this point most everyone has heard about Asteroid XF11's possible close encounter, or even collision, with Earth in 2028. Some say it will miss us by only 30,000 miles; others say it will miss us by 600,000 miles. I hope we can figure out just how far this thing will miss us by, or determine whether or not we're going to be clobbered.

In the meantime, when all this was breaking, an announcer on a Los Angeles radio station came up with a great name for the asteroid. He called it "El Kabong," probably after the alter-ego of cartoon character Quick Draw McGraw, the gun-toting horse in the old West. As El Kabong, McGraw would swing through the air, yell "Kabonnngggg!" and bash the bad guy in the head with a guitar. I think El Kabong is a perfect name for this asteroid. After all, these days we blame everything on El Niño: floods, drought, severe storms, the cat knocking over the valuable piece of china. Thirty years from now, we can blame everything on El Kabong. Besides, XF11 sounds like a foot powder. — *Jim Barton, Van Nuys, California*

Were Ancient Observers Really Keen-eyed?

I agree with Gerald Ruth ("Talking Back," January 1998) that some people glimpsed a crescent Venus before Galileo. But I'd like to suggest that the absence of reports from ancient Egypt, Greece, Babylon, India, China, or Mesoamerica, in addition to medieval Europe, must be due to some reason

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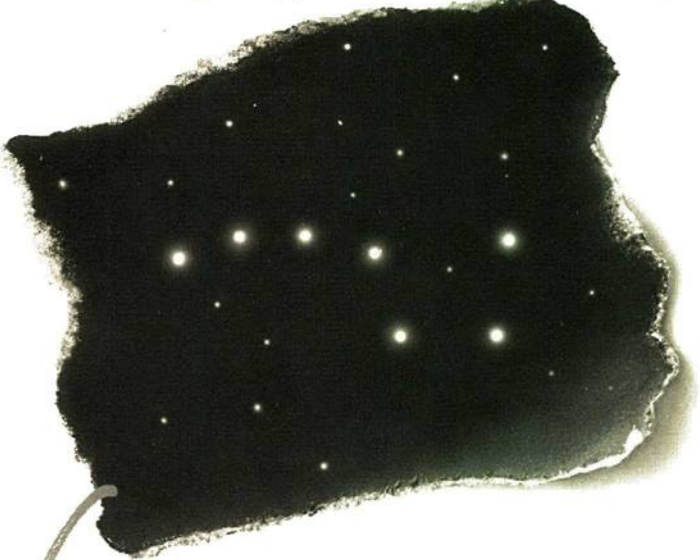

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other than that "people feared reprisals from those content with the Ptolemic earth-centered view."

How were teenage boys selected to be astronomers? (Sadly, girls need not have applied.) In traditional societies, the best qualification to enter a profession was to be the son or nephew of someone in the field. Maybe the youth with the best eyesight was behind a plow and stayed there because he hadn't been born into the elite of society. Before the invention of the Snellen eye chart and before smog and light pollution, a simple test would have been to spot the fainter constellations of the zodiac on a moonless night. Anyone who could tell Cancer from Libra and point to the circlet of Pisces would pass. If the youth could see stars of magnitude 4.5, his vision was sufficient to observe the planets. Most sons of ancient astronomers qualified — there wasn't a process in place to select those with the best vision from the entire population. In fact, to be a respected and successful astronomer, it was more important to have a good memory, math skills, and empathy for anxious clients than to have 20/20 vision.

Suppose an ancient observer saw a crescent Venus. He would not believe his eyes, so he might ask someone else, "Do you notice anything unusual about Venus this evening?" Based on statistics given by Ruth, the most probable answer would have been no, with a less than 10 percent chance of "Hmm, it does look a bit out of the round." How could the man with superior eyesight confirm this sighting? He would probably watch Mercury, Mars, Jupiter, Saturn — maybe even Antares and Regulus when they neared the sun — and not see any crescents. Since he could not discern a half-moon phase on Venus, let alone a gibbous shape, he couldn't begin to guess that Venus orbits the sun closer than Earth does. He would invite ridicule or worse if he claimed a discovery based on superior eyesight — consider the analogous case of Percival Lowell and the canals he clearly saw on Mars.

Isolated individuals over the millennia quite likely saw a crescent Venus, a moon or two of Jupiter, Uranus, and

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several Messier objects. But without optical aid, such sightings could not be confirmed by their peers and so were too dubious or unbelievable to even mention much less to write down for posterity. — *Michael J. Sloboda, Stanley, Hong Kong*

Subscription Winner

I write as the happy winner of a year's subscription to *Astronomy* magazine, having won this as a door prize at the 1998 Peach State Star Gaze in Jackson, Georgia. Thanks very much for your kind donation to the event. I happen to be very much a beginning amateur astronomer — in fact, the Peach State Star Gaze was only the second astronomy event I've ever attended. I really look forward to reading *Astronomy* and learning more about this hobby. — *Scott Deitchman, Decatur, Georgia*

In Words I Can Understand

What helps me — and a reason I have switched to *Astronomy* over other magazines — is the intelligent writing/editing that begins at floor level and tries always to translate quantities and distances into words that everyday people can understand. Like in "Seeing Double With Mira," December 1997, which read, ". . .only 0.6 arcsecond (the width of a dime seen four miles away)." I am never going to try to see a dime from four miles away, but the form gives me an idea of what 0.6 arcsecond is. (The only astronomical distances I have ever internalized are "a long way" and "a bloody long way"). — *Allan Hale, Perth, Australia*

Corrections

The photo on page 64 of the April issue was taken by Dennis Mammana, not Tony and Daphne Hallas, and the M101 image on page 99 of the April issue was taken by Jerry Lodriguss, not David Hanon. Our apologies. ■

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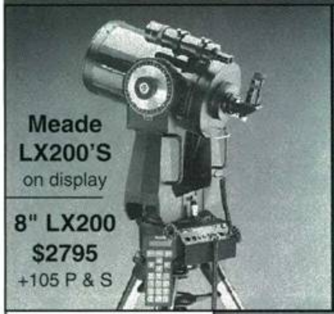

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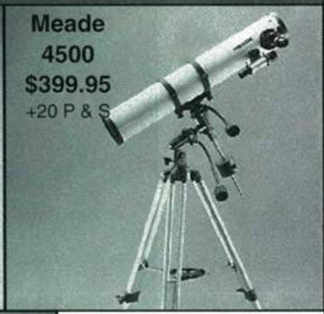

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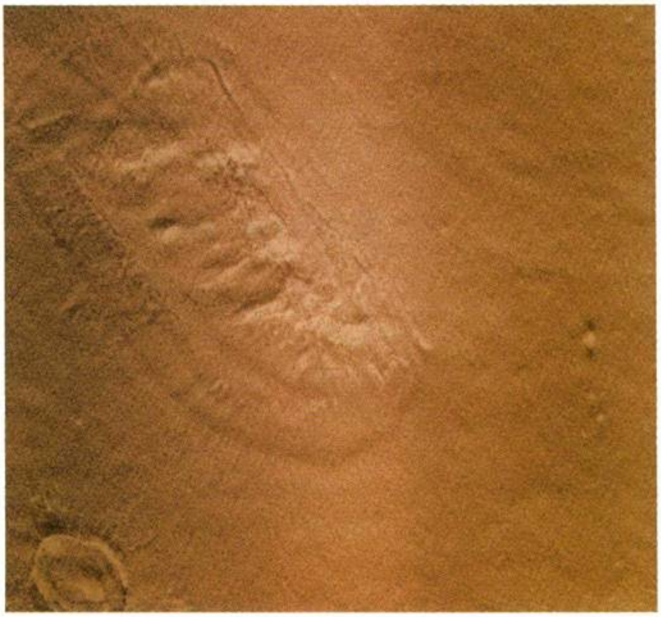
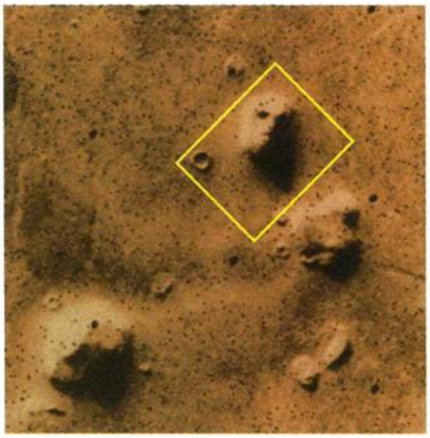
MARS GLOBAL SURVEYOR

Unmasking the Face on Mars

New Image Shows Eroded Hill





A high-resolution Mars Global Surveyor image above shows the "Face on Mars" to be a hill scarred by shoots and rubble piles indicative of landslides. A Viking image of the Face appears on the left, with the Mars Global Surveyor frame appearing inside the box. The Face itself is a mile across and a few hundred feet high. Mars Global Surveyor imaged it from a range of 276 miles (444 km).

Malin Space Science Systems/NASA

▶ No buildings, no highways, no flying saucers. A high-resolution Mars Global Surveyor image of the enigmatic "Face on Mars" radioed to Earth on April 6 shows a hill. The Face, and many of the surrounding structures in the Cydonia region, are remnants of ancient mountainous terrain that have been gradually eroded over the eons by wind, water, and ice.

Based on Viking orbiter images from the 1970s, some people claimed that the Face was an artificial structure. They cited pyramid-shaped features in Cydonia as further evidence that a technological civilization once existed on Mars. Most scientists, however, dismissed these claims, arguing that the Face and pyramids were natural formations seen at low resolution. The Mars Global Surveyor image has a resolution of 14 feet (4.3 meters), ten times sharper than the best previous image of the Face.

While the Mars Global Surveyor image might not convince die-hard believers, "Most reasonable people will look at the new picture and realize it's just one of these examples of something that looks familiar at one scale but not when you see it in more detail," says geologist Tim Parker of NASA's Jet Propulsion Laboratory.

Michael Ravine, advanced projects manager at Malin Space Science Systems (the company that built and operates Mars Global Surveyor's camera for NASA), says the image was posted on the World Wide Web as soon as it could have been. "If people are willing to invoke evil government conspiracies, ultimately there's nothing I can say to that. But if anyone associated with NASA had any unambiguous evidence of extraterrestrial life, they would not be trying to keep it a secret. If we saw alien artifacts at the base of this thing, Dan Goldin would be up on Capitol Hill explaining how we needed to double NASA's budget to send people to Mars."

The Face image, along with other Mars Global Surveyor images of the Cydonia region, can be viewed at: http://www.msss.com/mars/global_surveyor/camera/images/index.html.

GALAXY FORMATION

Astronomers Smash Distance Record

▶One of the universe's most mysterious metamorphoses occurred when the smooth distribution of matter from the Big Bang first clumped into gas clouds, stars, and eventually galaxies. Nobody knows exactly how or when the transformation occurred, but Arjun Dey of Johns Hopkins University and colleagues have recently spotted the most distant galaxy ever observed, documenting the earliest known time when a galaxy existed.

Using the 10-meter Keck II Telescope in Hawaii, the world's largest, Dey's team discovered a galaxy called 0140+326RD1 in September 1997. A spectrum taken at Keck four months later confirmed that light left this 26th-magnitude, fuzzy, red blob when the universe was only six percent its present age, less than one billion years after the Big Bang. Astronomers are surprised that any galaxy, including RD1, which is smaller and dimmer than our Milky

(see "Distant Galaxy," p. 24)

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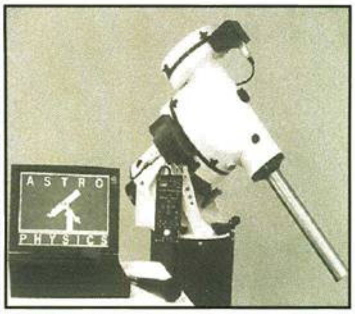

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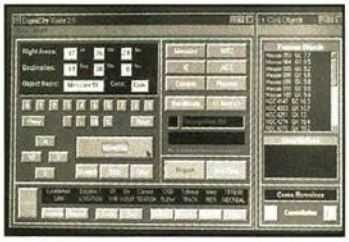

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PLANETARY NEBULAE

Hubble Catches the Youngster Stingray

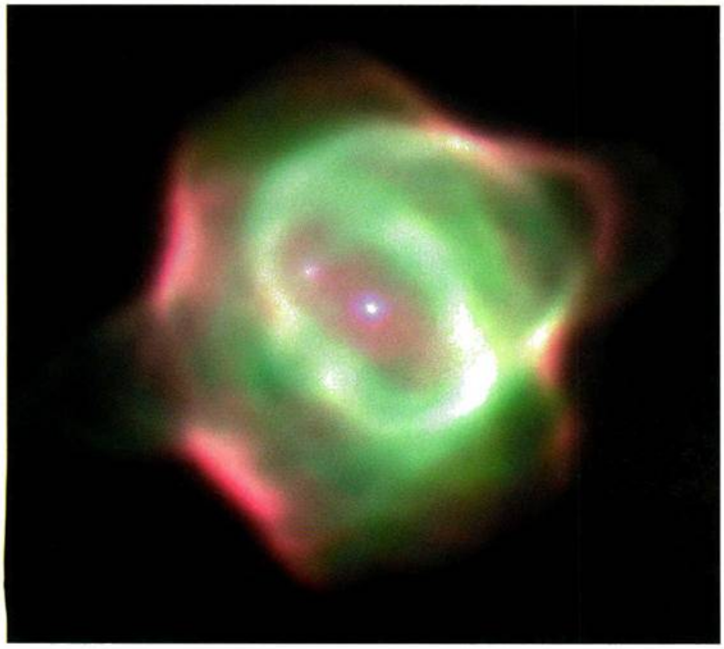
▶The Hubble Space Telescope has captured a fleeting moment in the life of a star, the instant when it flips the on switch to light up its planetary nebula. By catching a planetary nebula — the gaseous shroud of a dying star — in such an early stage of formation, the Hubble image is helping astronomers understand how most of these objects assume complex shapes.

The planetary nebula is known as the Stingray Nebula, which is located in the southern constellation Ara. The nebula is so small (only 0.1 light-year across) and so far away (about 18,000 light-years) that its detailed structure, including the presence of a companion star, could not be resolved by ground-based telescopes.

A planetary nebula forms when the core of a low-mass star like the sun runs out of nuclear fuel. The dying star throws off its outer layers, which form a shell around the star. The star's core shrinks and heats up, eventually becoming hot enough to cause the surrounding nebula to glow.

"In human terms, the Stingray Nebula is just an infant because only within the

(see "Stingray," p. 26)



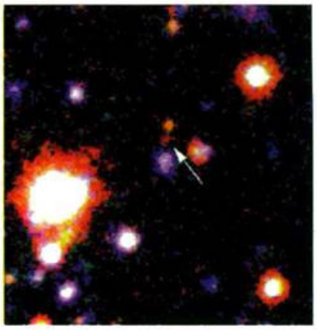
In this near true-color Hubble image of the Stingray Nebula, oxygen gas is green and nitrogen gas is red. Both gases are heated and ionized by radiation from the dying central star. A dimmer companion star lies to the central star's upper left. A ring of gas surrounds both stars.

Matt Bobrowsky (Orbital Sciences Corp.) and NASA

(Distant Galaxy)

Way, could have formed so soon after the Big Bang.

"It certainly is very interesting that they found such a large galaxy so early in the universe," said Barbara Ryden, a galaxy expert at Ohio State University. "It means you had structure forming quite early on." But Ryden says a single galaxy might be a fluke, so many more early galaxies must be found and studied before the riddle of galaxy formation can be understood.



The arrow in this false-color image points to the most distant galaxy yet discovered, a galaxy so distant its light left about 12 billion years ago.

Arjun Dey (Johns Hopkins University), et al.

The expansion of the universe "stretches" light from distant galaxies, causing it to shift to redder (longer) wavelengths. The farther away a galaxy, the greater its redshift. Until RD1 was discovered, no galaxy had a redshift (or "z value") greater than 4.92, which means the wavelength of light reaching us from the galaxy has increased 5.92-fold (z + 1). RD1, however, was found to have a redshift of 5.34, meaning its light has been stretched more than six-fold. Despite smashing the redshift 5 barrier by a fairly substantial margin, Dey predicts that the 5.34 record will be broken "in a matter of months." He adds, "Now that we know there exist galaxies at redshifts beyond 5, I expect that it won't be long until other searches are successful. Since our discovery is clearly due to our improved technology, we are entering a new era in the investigation of the high-redshift universe."

As this issue was going to press, University of Hawaii astronomer Esther Hu and colleagues were reporting the discovery of a source with a redshift of 5.64.

HUBBLE SPACE TELESCOPE

Amateur Studies Starburst

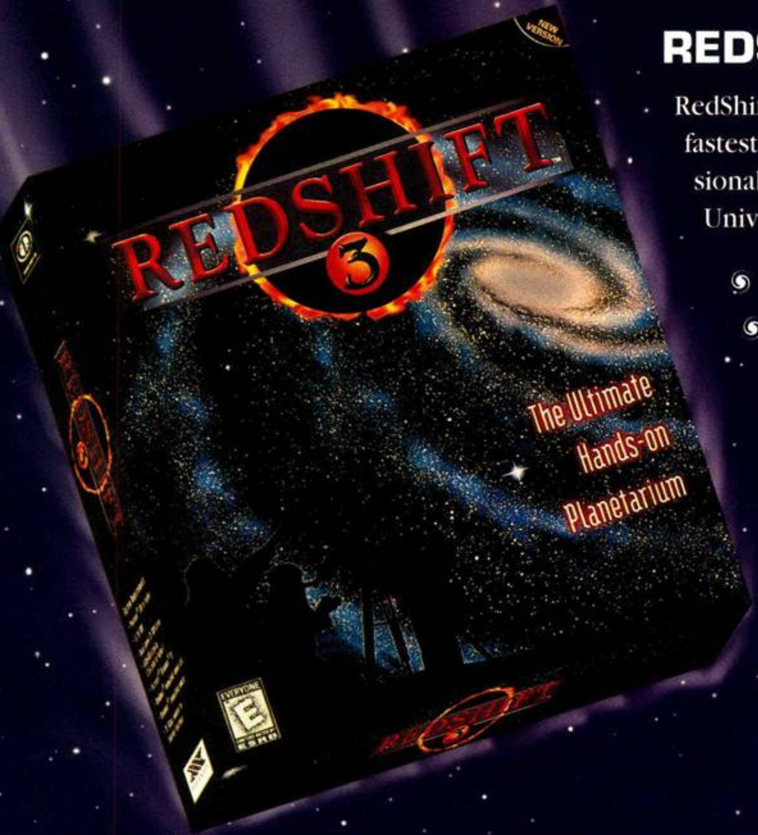
▶Most amateur astronomers only dream of using an instrument like the Hubble Space Telescope. Analytical chemist Jim Flood of New Jersey is one of the few who has. In the last of the 13 amateur astronomer observing programs on Hubble, Flood and professional astronomer Max Mutchler of the Space Telescope Science Institute teamed up to obtain a dramatic image of the barred spiral galaxy NGC 1808.

This galaxy is roughly 40 million light-years away in the southern constellation Columba. Its large size and brightness, relatively nearby location, and attractive appearance all made it an ideal target. "NGC 1808 is a nice spiral spewing dramatic amounts of dust and gas from the core," says Flood.

The Hubble image shows vigorous star formation

(see "Starburst," p. 26)

Meet Three Stars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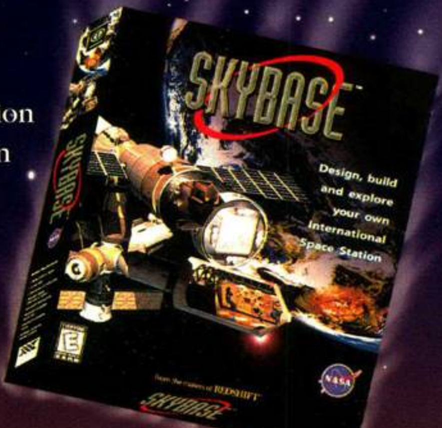
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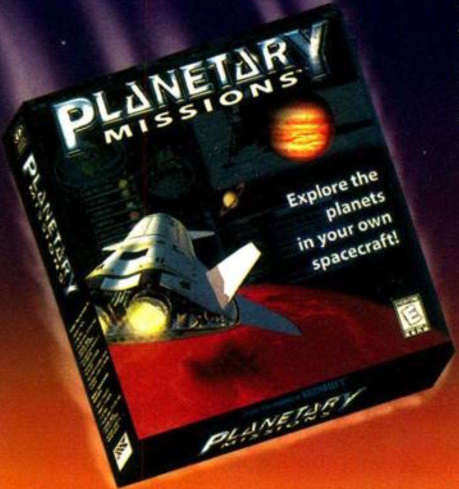
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(Stingray)

past 20 years did its central star rapidly heat up enough to make the nebula start to glow," says Matt Bobrowsky of Orbital Sciences Corporation, principal investigator for this observation. "It is extraordinary to catch a star in this exceedingly brief phase of its evolution. While stars typically last for billions of years, the transition to a visible planetary nebula takes only about 100 years — the blink of an eye compared to the star's lifetime."

The Hubble image shows a 5,000-AU-wide ring of gas surrounding the two stars. The ring appears to be constricting the flow of gas, forcing twin bubbles of gas to flow away from the dying central star in directions above and below the ring plane. A stellar wind of hot gas appears to have punched holes through the upper portions of each bubble, allowing gas to escape into the surrounding space. The nebula could eventually assume a variety of non-spherical shapes typical of many planetary nebulae.

Current theory suggests that these complex shapes arise when a disk or ring constricts the flow of gas from a dying star. But Bobrowsky says the Hubble Stingray image hints that the process is more complicated than that. The Stingray's bubbles appear to be acting like nozzles, collimating the stellar wind into twin narrow jets flowing perpendicular to the ring.

(Starburst)

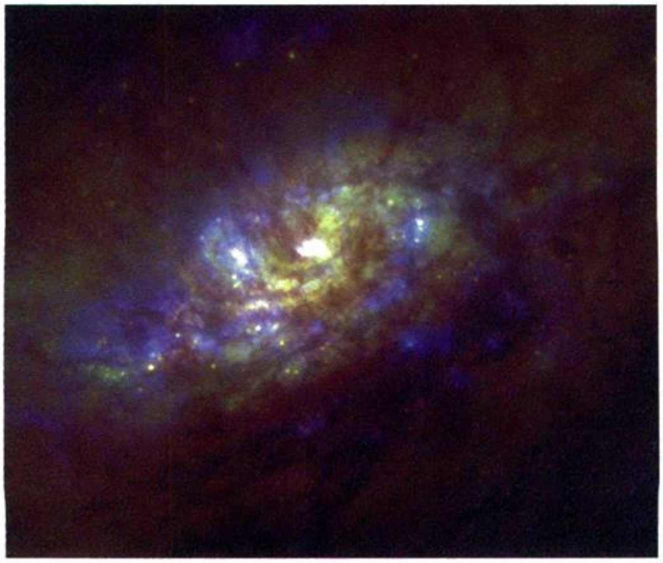
taking place at the galaxy's center. This "starburst" is probably the result of gravitational interactions with the nearby galaxy NGC 1792. Blue star clusters shine amid thick lanes of gas and dust. Hubble shows that these stars are often born in compact clusters within the starburst region and that the dense gas and dust required for star birth heavily obscures these stellar nurseries. The brightest knot of star birth is probably a giant cluster (roughly 100 light-years in diameter) at the very center of the galaxy. The other clusters are 10 to 50 light-years in diameter.

"I've learned that the Space Telescope gathers more information than professional astronomers can possibly look at, and I plan to take advantage of the public domain nature of all Hubble data after a one-year period to do further research," says Flood.

Mutchler adds, "This was the last of the 13 official Hubble amateur programs, but amateurs continue to play an important role in Hubble research on an informal basis."

The Hubble image (right) shows clusters of hot, young, blue stars in a 3,000 light-year section of NGC 1808's starburst region. The ground-based image (left) shows a faint halo surrounding the galaxy's disk — the aftereffect of dust filaments being ejected from the core by massive stars that exploded as supernovae in the starburst region.

Jim Flood, Max Mutchler (Space Telescope Science Institute), and NASA



GALAXY EVOLUTION

Blue Dwarf Galaxies Not Infants

▶One of astronomy's biggest unanswered questions is whether galaxies continue to form now or whether they were all created in the distant past. Blue dwarf galaxies — compact objects about the size of globular clusters — have been considered the best candidates for newly forming galaxies. But recent Hubble Space Telescope observations indicate otherwise.

Blue dwarf galaxies are generally so small and so distant that ground-based telescopes cannot resolve their individual stars. Regina Schulte-Ladbeck of the University of Pittsburgh and her colleagues Mary Crone of Skidmore College and Ulrich Hopp of the Munich Observatory used Hubble's Wide Field Planetary Camera to resolve the stars in the blue dwarf galaxy VII Zwicky 403, the closest blue dwarf to Earth. As expected, this galaxy contains a large number of hot, young, blue stars. Surprisingly, the Hubble image also revealed many red giant stars, which are much older.

The presence of red giants means that VII Zwicky 403 is not a newly forming galaxy but is rather a galaxy that has recently undergone a burst of star formation. "We are clearly not looking at a young galaxy. This is one important piece in the puzzle of when all the galaxies formed; this

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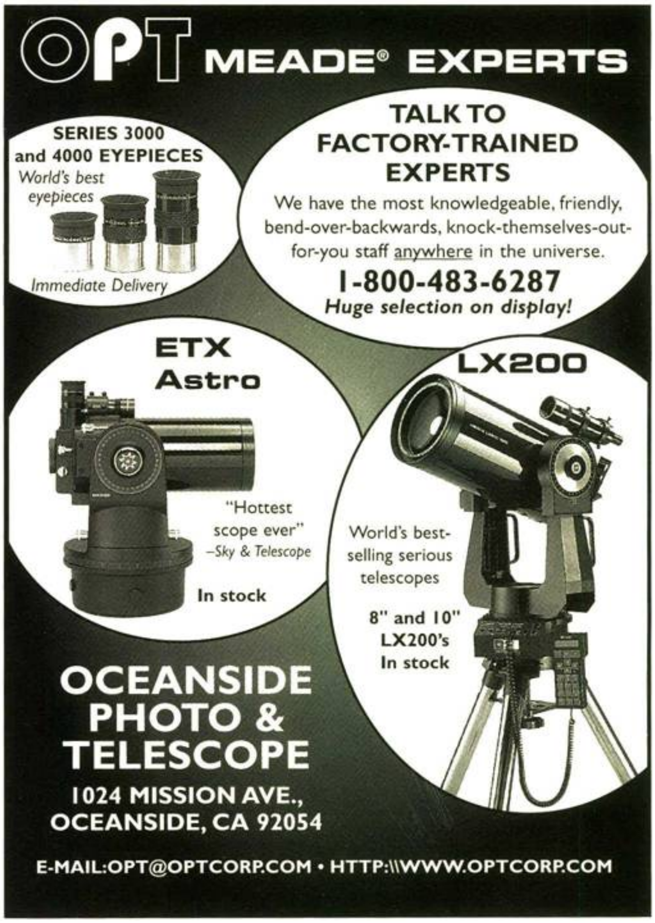

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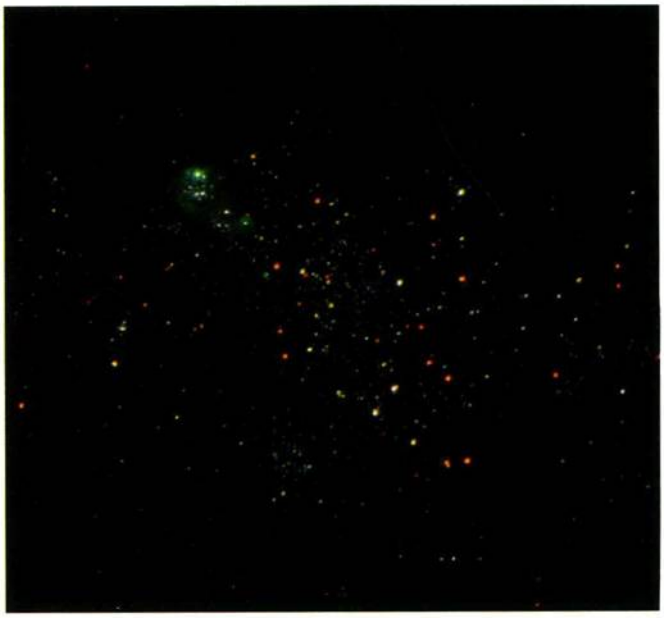


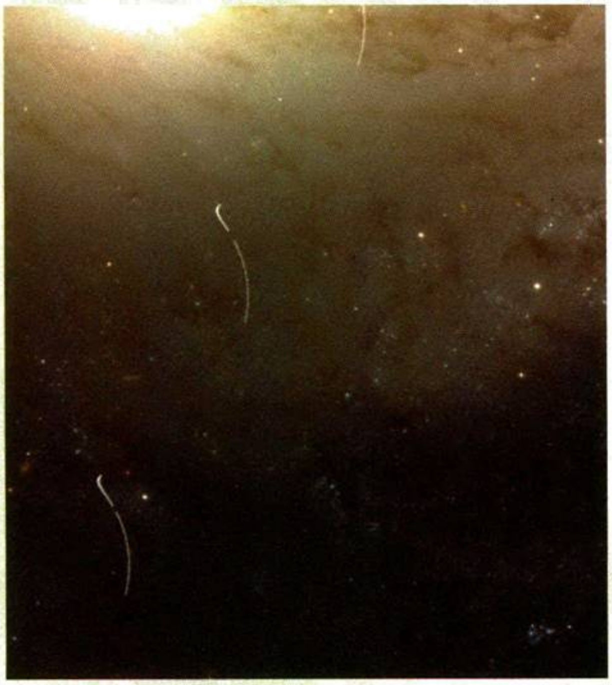
In this Hubble image of the blue dwarf galaxy VII Zwicky 403, 15 million light-years away, the bright blue stars are hot and young, while the bright red stars are supergiants. The faint red stars are old red giant stars, which indicate that this is not an infant galaxy as once suspected.

Regina Schulte-Ladbeck (University of Pittsburgh), et al., and NASA

evidence shows that galaxy formation is unlikely to be an ongoing process," says Schulte-Ladbeck. She and her colleagues will use Hubble to look for red giant stars in other blue dwarf galaxies, which should tell astronomers how long ago these galaxies formed.

— JENNIFER BIRRIEL

ASTEROIDS



ASTEROID GOLD MINE Astronomers Robin Evans and Karl Stapelfeldt of NASA's Jet Propulsion Laboratory have bagged a sizable cache of 96 small asteroids (0.5 to two miles across, or one to three kilometers) from an unexpected source: an archive of 28,460 Hubble Space Telescope frames. Most astronomers look through stored Hubble images for bigger quarry such as quasars, distant galaxies, or supernovae. Evans and Stapelfeldt weren't originally looking for asteroids either until Stapelfeldt's wife, JPL astronomer Deborah Padgett, spotted one in a Hubble image on their home computer in 1994.

The asteroids show up as long, curved streaks (an example is shown above, with galaxy NGC 4548 in the background) due to the telescope's curved orbital motion around Earth. By extrapolating their numbers over the entire asteroid belt, Evans and Stapelfeldt estimate a total population of 300,000 asteroids between half a mile and two miles wide. All of their asteroids were found in the main belt between Mars and Jupiter. "We were at the right place at the right time to see them and recognize what they were," says Stapelfeldt, who adds, "We're not going to be naming any of them, because it's unlikely that we'll ever see any of them again. You need a full orbit to name an asteroid."

Robin Evans and Karl Stapelfeldt (Jet Propulsion Laboratory) and NASA

GALILEO

New Dust Ring for Jupiter

▶When you think of planetary rings, the ones around Saturn always come to mind first, followed by the less spectacular though still intriguing systems of Uranus and Neptune (see "Ruling the Rings," page 54). But Jupiter's ring — a tenuous and essentially featureless collection of tiny dust particles — always seemed to be a poor cousin to those of the other gas-giant planets.

That's changed now. New computer simulations combined with observations by the dust collector onboard the Galileo spacecraft show that Jupiter possesses a second ring.

A team led by Joshua Colwell of the University of Colorado found a faint, doughnut-shaped ring of interplanetary and interstellar dust particles. The new ring spans 700,000 miles and is so tenuous that a single photon of light sent through it would have less than a one-in-a-billion chance of hitting a dust grain. This makes it much larger and more sparse than the main ring, discovered in 1979 by Voyager 2.

Surprisingly, most of the dust particles orbit Jupiter in the direction opposite the planet's rotation and the moons' orbital motions. No one has yet figured out why the particles follow these "retrograde" orbits.

The ring forms as Jupiter's powerful magnetic field captures interplanetary and interstellar dust grains that are roughly the size of particles in cigarette smoke. "If the particles are just the right size, they lose energy to the magnetosphere and are

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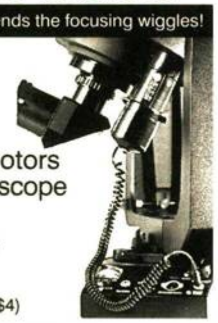

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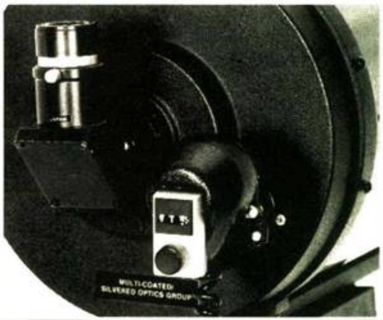

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captured in the ring," says Colwell. Larger grains have too much energy to be captured while smaller grains are deflected away by the magnetosphere.

Although the ring appears unique in the solar system, "I suspect Cassini may wind up seeing something similar at Saturn when it arrives in 2004," says Colwell, because Saturn also possesses a powerful magnetic field.

IMPACT CRATERS

Dinosaur Killer Sheds Light on Mars

▶Sixty-five million years ago the lights went out with a bang for the dinosaurs and many of Earth's other creatures. The favored culprit is a massive comet or asteroid that slammed into what is now Mexico, blanketing the skies with dust and setting off a global cooling. A team led by Adriana Ocampo of NASA's Jet Propulsion Laboratory and Kevin Pope of Geo Eco Arc Research in California has recently discovered two new sites related to the deadly impact, one of which could reveal clues about the environment on Mars long ago.

When the object hit Earth, it excavated a crater some 120 miles (200 km) wide centered on the coastal town of Chicxulub on the Yucatán Peninsula. The impact was so powerful, says Ocampo, that "material was thrown from the crater — it went ballistic." Much of this debris later rained back down to Earth. But some of the ejecta flowed along the surface away from the crater, forming lobes shaped like flower petals.

One of the sites, in Alvaro Obregon, Mexico, is the nearest example yet of ejecta thrown from the crater. Only 140 miles (230 km) from the crater rim, the two geologists found layers of rock tens of feet thick that had flowed like molasses across the surface.

While finding such impact ejecta is rare on Earth, much of the surface of Mars — which has remained relatively unchanged for billions of years — is covered by ejecta debris from "splosh" craters, which also have ejecta lobes shaped like flower petals. How the splosh craters formed remains a mystery. Some scientists suspect that they were created by an abundance of water ice near the surface, turning the ejecta into a thick, muddy fluid. But others think they were created as flying material from an impact flew through a martian atmosphere much thicker than the one at present. Slowed by friction into a dense cloud, the debris would have also flowed like water on the surface.

Chicxulub was under an estimated 165 feet (50 meters) of water when the object hit Earth. So by studying fluidized ejecta material on Earth, the researchers hope to determine whether water, air, or both made the formations on Earth — and on Mars. — **Gretel Schueller**

WEBSITE

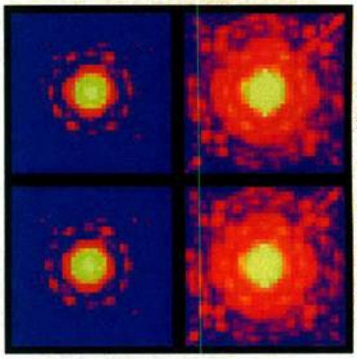
Check *Astronomy*'s website for news as it happens — http://www.astronomy.com

Tasco to Acquire Celestron

On March 25th, 1998, Tasco Sales, Inc. (an international sports optics distributor) signed a letter of intent to acquire Celestron International (a high-end optics company and one of the world's largest telescope manufacturers). "We are very pleased that Celestron chose Tasco among its many suitors to forge ahead with this transaction," said Tasco President and C.E.O. W. Greg Bland. "This partnership allows Tasco to accelerate its growth in the high-end optics market with Celestron's established and well-respected brand name."

No Proxima Planet, Probably

Astronomers using the Hubble Space Telescope's Faint Object Spectrograph created excitement in early 1998 with a report that they had imaged a possible planet or brown dwarf orbiting Proxima Centauri, which at a distance of 4.2 light-years is the sun's closest stellar neighbor (see "Proxima Planet?" AstroNews, February 1998). But more recent and more sensitive observations from Hubble's Wide Field/Planetary Camera 2 by David Golimowski of Johns Hopkins University and Dan Schroeder of Beloit College show no evidence for a brown dwarf or planet companion. Says Golimowski: "We have images of Proxima that definitely should have revealed something. They did not."



David Golimowski (J.H.U.), et al., and NASA

Four recent Hubble images of Proxima Centauri show the star and diffraction rings, but no substellar companions.

Arecibo Guaranteed Quiet Time

One of the biggest threats to radio astronomy is interference from Earth-orbiting satellites. Among the greatest perils is the new Iridium satellite network, a system of 66 satellites that will provide mobile phone communications beginning this autumn. The satellites will downlink at a frequency near 1612 megahertz, the same frequency at which the astronomically important hydroxyl molecule emits. Against this backdrop, radio astronomers reached a compromise with Iridium's owner, Motorola, to provide eight hours a day of quiet time for the 1,000-foot Arecibo radio telescope in Puerto Rico. Although the agreement provides some respite for astronomers, many fear that the interference problem will only grow worse in the future.

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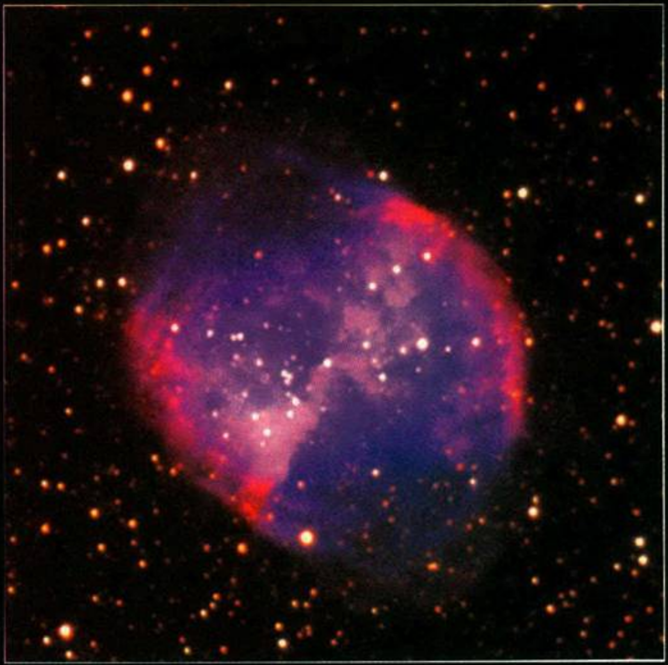

M27 Planetary Nebula. As in all the planetary nebulae, the faint central star is an abnormally hot bluish dwarf with a spectrum resembling that of an ancient nova and a calculated surface temperature of about 85,000 degrees K., one of the hottest stars known. It is assumed that planetaries are formed by ejection of material from the hot central star, but the exact details of the process are unknown. Red, Green, and Blue Model ST-7 images were summed together and color balanced to create a true color image. *Courtesy of Benoit Schillings.*

Note: All images were processed from a computer disk to a standard photographic film using a Film Recorder. Courtesy of AstroPhoto, Oakview, California.

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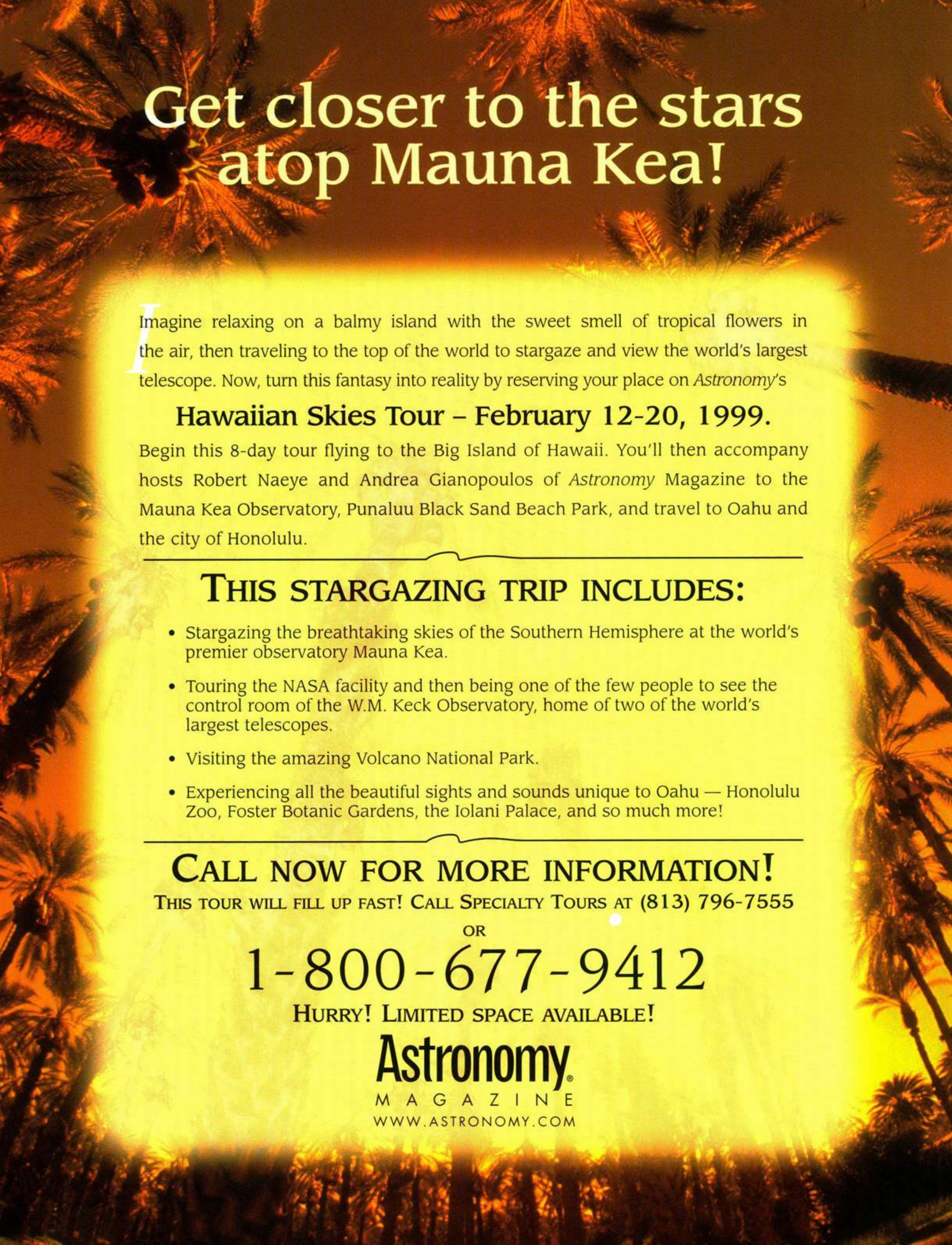

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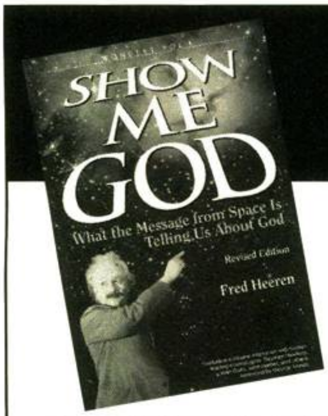

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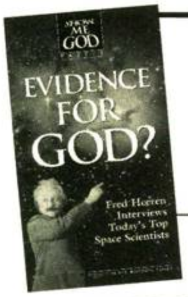

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ask Astro

3-D Images, Colliding Galaxies, Cosmic Dust.

Q: How did you make a 3-D photograph of Supernova 1987A in your March issue? I didn't think you could even get a measurable parallax of something that remote. — *Mark Hoadley, Ipswich, Massachusetts*

A: You're absolutely correct. The short answer: We cheated! (Or more accurately, the artist we hired to process the supernova image cheated.) Most of the 3-D images in the March issue, including all of those in the Mars Pathfinder article, were true stereoscopic 3-D images, in which two images taken from slightly different vantage points were combined to give a realistic 3-D perspective.

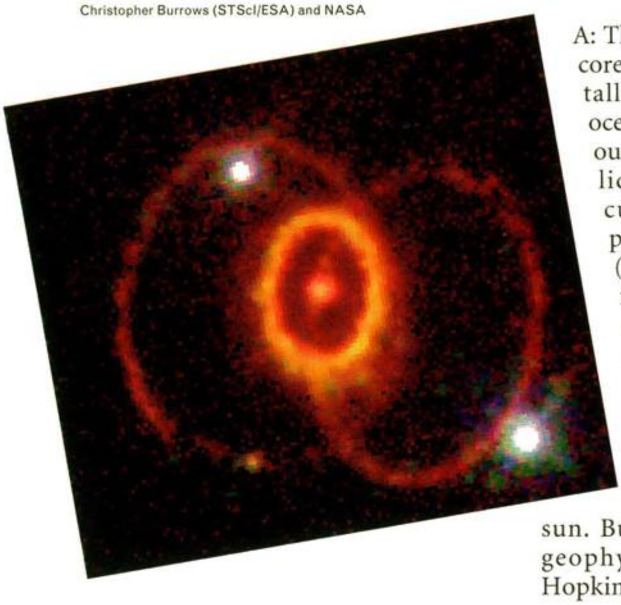
People see 3-D the same way: Our two eyes are an inch or two apart, so each eye sees an object from a slightly different angle. The brain combines the perspectives into a single image, enabling us to see 3-D and accurately judge distances.

But for some of the 3-D pictures in the March issue, including all of the Hubble Space Telescope images, the objects are too far away to create a true stereo effect. So the three-dimensionality was artificially created on a computer. The orientation of Supernova 1987A's rings was represented accurately, but the apparent positioning of foreground and background stars does not necessarily correspond to their actual positions in space.

To see more 3-D images, go to our website: http://www.astronomy.com. — *the editors of* Astronomy

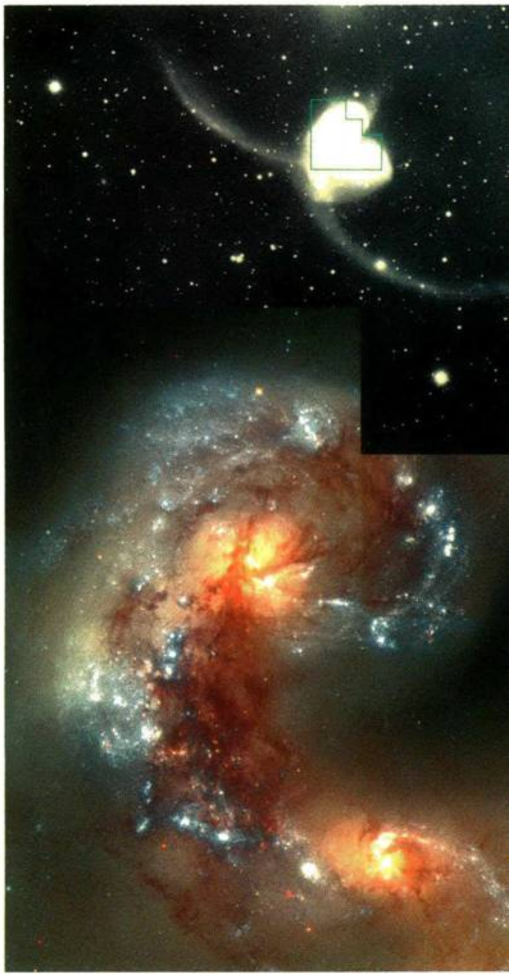
Supernova 1987A is 167,000 light-years away, too far to get a realistic 3-D effect.

Christopher Burrows (STScI/ESA) and NASA



Q: Earth's interior is made of different layers, one of which is in a molten state. Will this layer solidify? If yes, in how many years will it happen and what effect may it have on our climate? — *Roland Le Houillier, Quebec City, Canada*

A: The questioner is right: The inner core of Earth is solid, and it is crystallizing out of the wraparound ocean of molten iron known as the outer core. The circulation of that liquid metal sets up electrical currents that create about 98 percent of Earth's magnetic field (the other two percent comes from magnetized minerals in rocks). If the outer core suddenly froze solid, the magnetic field that remained would be too weak to navigate by and much too feeble to fend off the deadly wind of charged particles from the sun. But don't worry: According to geophysicist Peter Olson of Johns Hopkins University, in the 4.5 billion or so years since our planet took shape, only about four percent of the iron in the outer core has solidified. At that rate it will take another 100 billion years for hell to freeze over. — *Robert Coontz,* Earth *magazine*



Despite the expanding universe, galaxies can and do collide, as evidenced by this Hubble Space Telescope image (bottom) of NGC 4038 and NGC 4039 (commonly known as the Antennae). A ground-based Antennae image is at the top. Brad Whitmore (STScI) and NASA

Q: If the universe is expanding and all the galaxies are moving away from one another, how could galaxies ever collide? — *Kathy Heiberg, Ventura, California; Patrick Edouard, Lansing, Illinois; Timothy Ford, Spring, Texas; Guillermo J. Morales, San German, Puerto Rico; Jack Ellwood Steele, Summerland Key,*

Florida; and Basim Al-Boutie, Kuwait City, Kuwait

A: The problem here is a matter of scale. When astronomers measure the expansion of the universe, they are talking about expansion over distances of hundreds of millions (or billions) of light-years. Galaxies themselves, however, tend to cluster on scales of perhaps only a few tens of millions of light-years.

For example, the Local Group, the cluster to which the Milky Way belongs, is only about 10 million light-years across. On that scale, the gravity of the cluster is easily more than enough to counteract the general expansion of the universe. It's like firing a rifle backward out of a moving car. The bullet travels much faster than the car, moving backward relative to the car. Because of the car's forward motion, an observer standing outside the car would see the bullet moving a bit slower than would someone inside the car. In our case, the Local Group is expanding a bit due to the general expansion of the universe, but this expansion is dominated on the small scale by the gravitational pull of the galaxies. So inside a cluster, galaxies can move faster than the universal expansion, and if two galaxies happen to be headed toward each other, they will indeed collide. — *Phil Plait, Advanced Computer Concepts, Inc.*

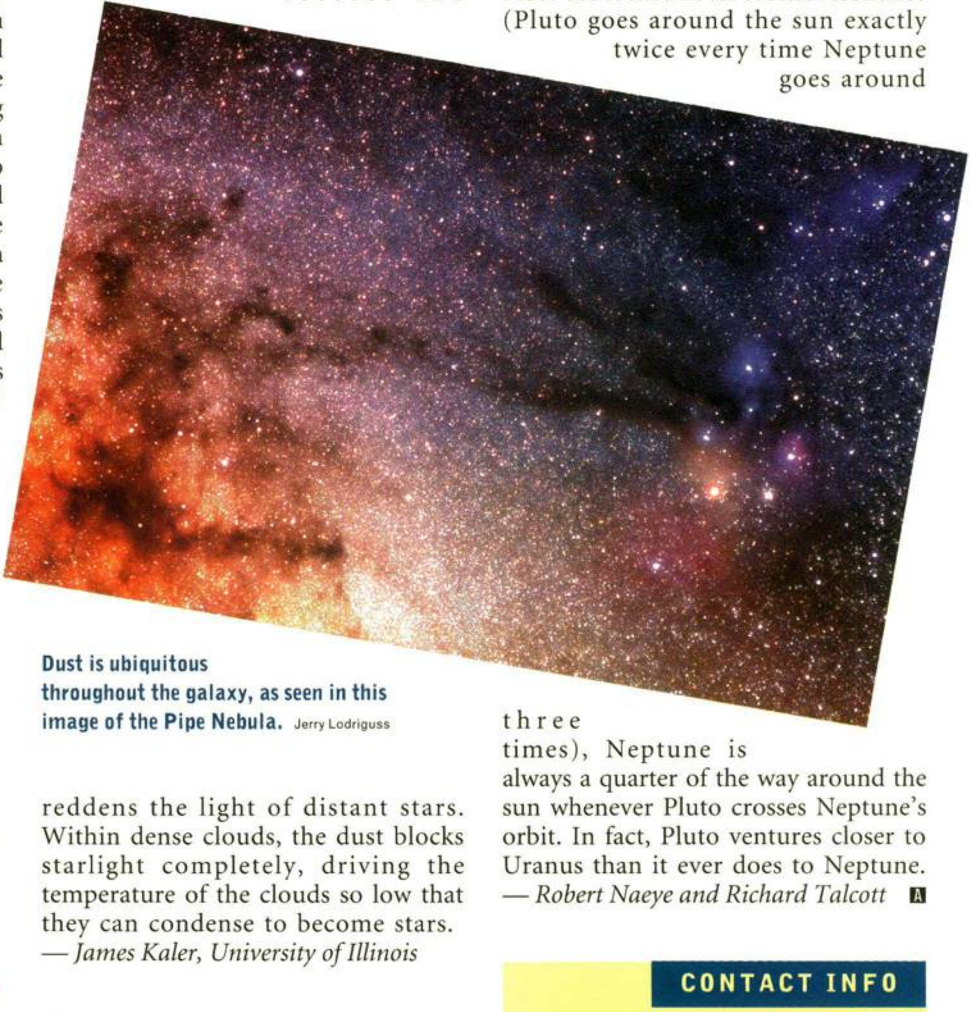
Q: What exactly is dust in an astronomical context, the kind that is found in nebulae and galactic clouds? How is it different from the dust that accumulates on the top of my refrigerator?

— David P. Knezz, Western Springs, Illinois; Joe Calabria, Doylestown, Pennsylvania; and Ronald Kohl, Lakewood, New York

A: The dust on my refrigerator consists of fibers, organic flakes, and dirt particles and is easily and unfortunately visible to the naked eye. Interstellar dust is quite different. The grains are tiny, only a thousandth of a millimeter or so across or less, and could not be seen without a microscope.

The base compositions of the particles are either silicates, ejected from oxygen-rich Mira variable stars, or amorphous carbon (like graphite) ejected from the carbon-rich versions. Once in interstellar space, the grains pick up ices and metal atoms, depleting a variety of heavy elements from the ambient gas.

The dust is very thinly spread. On average (excepting dense clouds), there is only one grain or so per cubic meter. Interstellar distances are so great, however (one light-year is 10^{16} meters long), that the dust easily absorbs and reddens the light of distant stars. Within dense clouds, the dust blocks starlight completely, driving the temperature of the clouds so low that they can condense to become stars. — *James Kaler, University of Illinois*



Dust is ubiquitous throughout the galaxy, as seen in this image of the Pipe Nebula. Jerry Lodriguss

Q: How long has Pluto been closer to the sun than Neptune, and when will it be more distant again?

— John Ferguson, Warren, Oregon and Tsangalas Evangelos, Larissa, Greece

A: Due to Pluto's highly eccentric orbit, it spends about 20 years out of its 247.7-year orbit closer to the sun than Neptune. In fact, Pluto at this very moment lies inside Neptune's orbit, making it the eighth planet (assuming that one considers diminutive Pluto to be a true planet). According to the latest orbital calculations, Pluto moved closer to the sun than Neptune on February 8, 1979, and will swing beyond Neptune on February 9, 1999 (mark your calendar!). Pluto won't slip inside Neptune's orbit again until 2231.

Even though Pluto moves inside Neptune's orbit, the two planets will never collide. Because Neptune and Pluto are locked in an orbital resonance (Pluto goes around the sun exactly twice every time Neptune goes around three times), Neptune is always a quarter of the way around the sun whenever Pluto crosses Neptune's orbit. In fact, Pluto ventures closer to Uranus than it ever does to Neptune. — *Robert Naeye and Richard Talcott*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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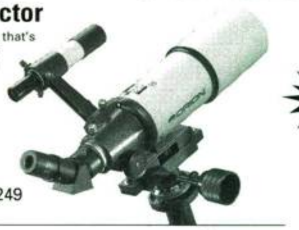

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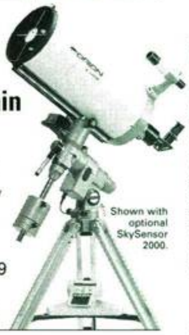

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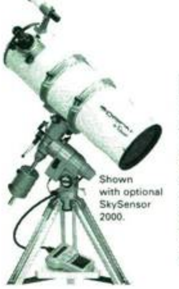

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LOOK

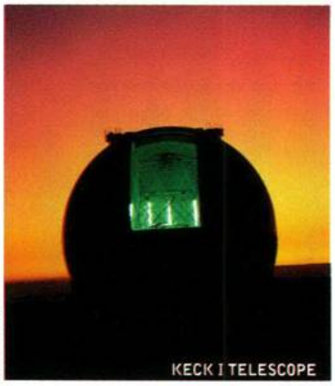
THE A LIST:

Astronomy's remarkable growth owes an immense debt to these 25 Earth-based telescopes and observatories.

- With a diameter of 1,000 feet, the Arecibo radio telescope in Puerto Rico is the largest telescope of any kind ever built and our most powerful ear on the radio universe.

- Although it hasn't lived up to expectations, the 6-meter Bolshoi Telescope in the Caucasus Mountains (the biggest in the world before the Keck Telescope) was the first large telescope to use a computer-controlled alt-azimuth mounting, the kind now used on most large telescopes.

- Cerro-Tololo InterAmerican Observatory in Chile opened the southern sky to modern inquiry with the first 4-meter telescope in the Southern Hemisphere.


KECK I TELESCOPE

Peter French

- Though Galileo did not invent the telescope, he was the first to turn one toward the heavens. With a modest 30-power scope, he discovered mountains and craters on the moon, spots on the sun, the phases of Venus, the four big moons of Jupiter, and the star-studded Milky Way.

- For three decades, the 200-inch Hale Telescope on Palomar Mountain in California reigned as the world's largest — and best.

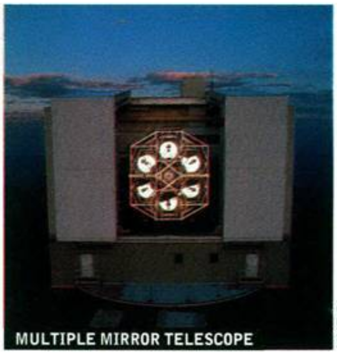
- William Herschel pushed telescope making to new levels in the 18th century, completing scopes as big as 48 inches in diameter and 40 feet long. With these assorted instruments he discovered the planet Uranus and catalogued thousands of double stars and nebulae.

- The 11-meter Hobby-Eberly Telescope at McDonald Observatory in West Texas was the first designed solely to take spectra of celestial objects.

- The horn antenna in Holmdel, New Jersey, was the first to pick up the faint echo of the cosmic background radiation, the single most decisive observation supporting the big-bang theory.

- The 100-inch Hooker Telescope on Mt. Wilson in California was the first to resolve individual stars in the Andromeda Galaxy and helped Edwin Hubble show that the universe is expanding.

- The twin 10-meter Keck telescopes located on Mauna Kea in Hawaii now reign as the world's largest and have pushed the frontiers of ground-based observational astronomy to new heights.


MULTIPLE MIRROR TELESCOPE

MMT Observatory

- Kitt Peak National Observatory in Arizona was the first facility that allowed astronomers from any institution in the United States access to a number of powerful telescopes.

- The Lick Observatory on Mt. Hamilton in California, a leading research institution since it began operations in 1888, was America's first permanent mountaintop observatory.

- Long a center of planetary astronomy, Lowell Observatory in Flagstaff, Arizona, was the

HALE TELESCOPE

Carnegie Observatories

BACK

EYES ON THE UNIVERSE

site where Clyde Tombaugh discovered the planet Pluto.

- *The summit of Mauna Kea hosts an array of powerful telescopes and provides astronomers with the finest ground-based views of the sky at optical and infrared wavelengths.*

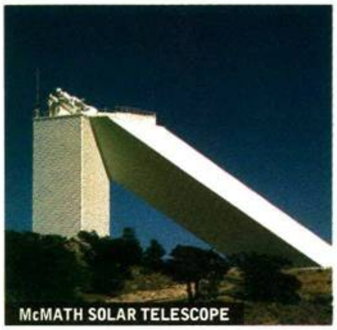
- *Although currently being fitted with a single 6.5-meter mirror, the Multiple Mirror Telescope in Arizona showed the feasibility of combining several mirrors into one telescope.*

YERKES 40-INCH REFRACTOR

Yerkes Observatory

- *The National Solar Observatory, consisting of Kitt Peak's McMath Telescope and the instruments at Sacramento Peak in New Mexico, have helped solar physicists understand how the sun works.*

- *The New Technology Telescope at the European Southern Observatory in La Silla, Chile, pioneered many successful innovations in telescope design and operation.*


McMATH SOLAR TELESCOPE

Jay M. Pasachoff

- *Isaac Newton built the first working reflecting telescope, the basic design now used by all of the world's largest telescopes.*

- *The 48-inch Schmidt telescope at Palomar Observatory took the first wide-field surveys of the sky, indispensable tools for astronomers even to this day.*

- *William Parsons, the Third Earl of Rosse, built a 72-inch reflector in Ireland and with it discovered the spiral structure of several distant "nebulae."*

- *Founded in the 17th century, Britain's Royal Greenwich Observatory and the Paris Observatory in France became the first national observatories, institutions whose prime mission at that time was to determine longitudes on Earth.*

ARECIBO RADIO TELESCOPE

Steven Ostro

- *Tycho's 16th-century Uraniborg Observatory in Denmark, though built before the telescope was invented, provided the accurate positions needed to determine how the planets moved.*

- *With its 27 separate antennae, the Very Large Array radio telescope in New Mexico can resolve the finest detail in radio-emitting objects.*

Astronomy 25 YEARS

- *The WIYN Telescope on Kitt Peak in Arizona launched a host of innovative ideas in telescope control and operation.*

- *The 40-inch refractor at Yerkes Observatory in Williams Bay, Wisconsin, has ranked as the world's largest refractor for the past 100 years.*

A BEAST IN THE CORE

Supermassive black holes probably lurk in the centers of all the big galaxies.

by Marcia Bartusiak

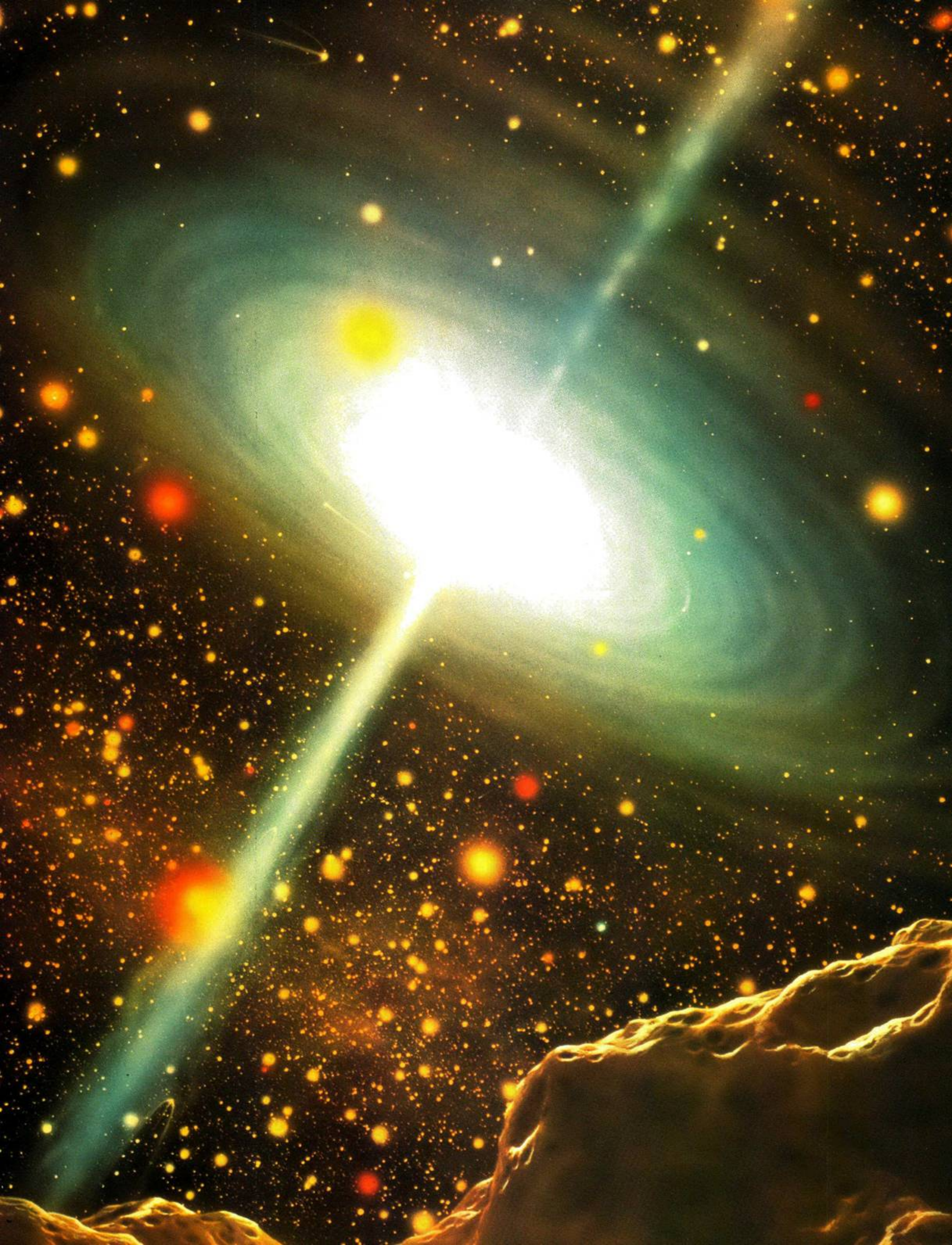
THERE'S NO STOPPING A DETERMINED astronomer. More than 30 years ago, when quasars were still a complete mystery, observers went to extraordinary lengths to learn their secrets. In 1963 Australian radio astronomers even cut down trees and tipped a weighty radio dish beyond its safety limits to pinpoint the radio signal of a quasar caught low on the horizon. It was 3C 273, which in the optical turned out to be a star-like object. After analyzing its spectrum, Caltech astronomer Maarten Schmidt realized that 3C 273 was not a star at all, but rather an ultraluminous object situated some two billion light-years away. By today's standards, that's relatively close by for a quasar — most are now found more than 10 billion light-years distant.

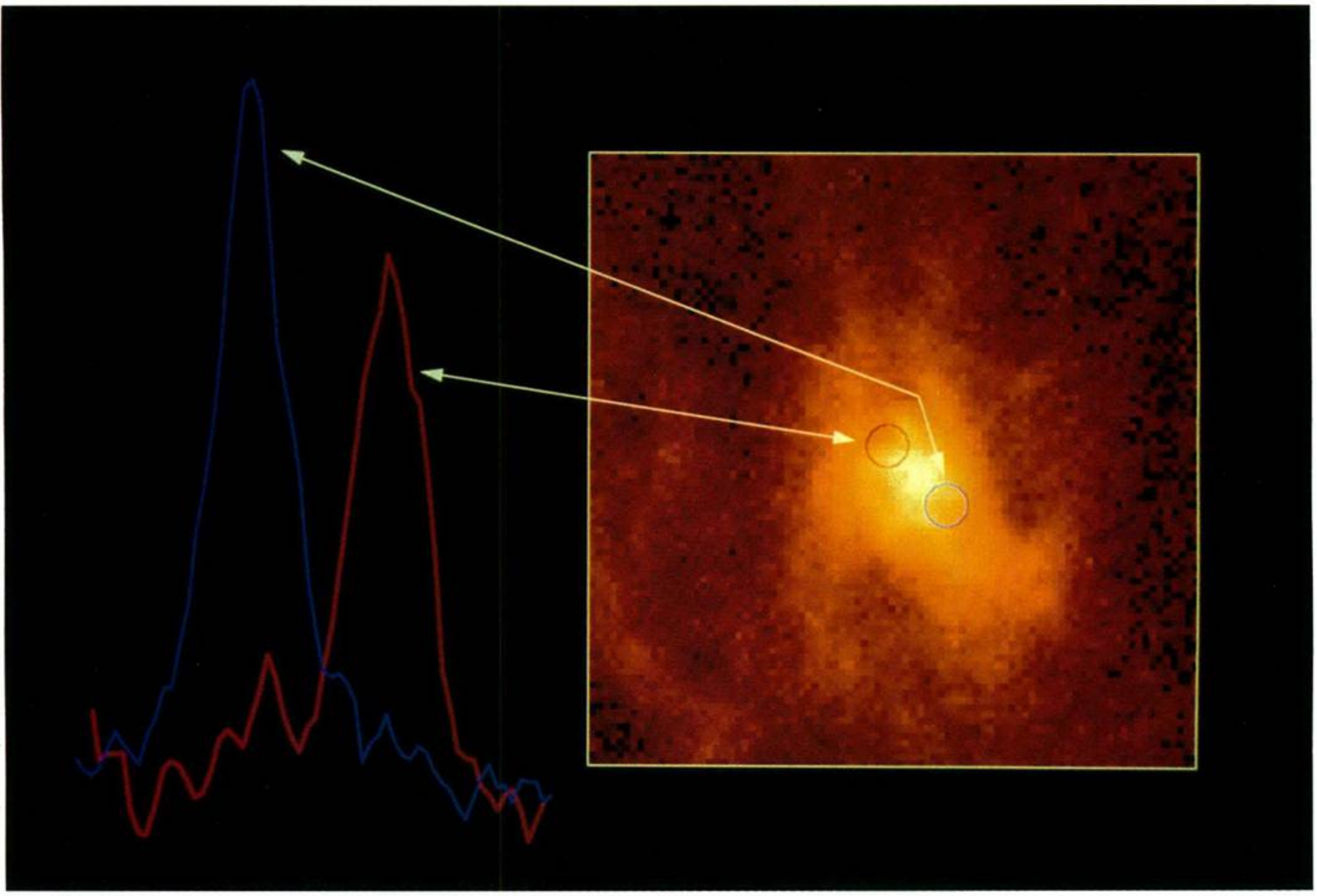
The Hubble Space Telescope is currently revealing quasars in startling detail. Where once astronomers saw only dots of light, they now see the glowing compact cores of far-off galaxies, each core pouring out the energy output of a staggering 100 galaxies crammed into a volume of space the size of the solar system. Some quasars appear to have been triggered by an interaction or collision with another galaxy. Other quasars, however, reside in relatively normal galaxies.

Exactly how a quasar turns on is still being debated, but most theorists agree it probably involves a humongous black hole, one that contains the mass of a million to ten billion suns. The black hole gravitationally attracts nearby matter and never lets it go. But before the material is permanently captured, it gathers into a swirling accretion disk that surrounds the black hole and radiates intensely. It's thought the black hole itself spins, like a giant magnetic dynamo, producing two jets of subatomic particles that shoot away in opposite directions from each pole at near the speed of light. All of this activity occurs as long as there is enough fuel nearby — stars, dust, and gas — to feed the dark monster in the middle.

Astronomers would love to observe this process more closely, but glare and distance effectively hide such awesome engines from prying astronomical eyes. It's like trying to examine the workings of a searchlight when it's beaming into your face. In recent years, though, a new line of study is finding a

A monster black hole probably lurks in the core of every major galaxy, including our own. Some of these black holes, as shown in this painting, power jets of subatomic particles that travel across *hundreds of thousands* of light-years at near light speed. *Astronomy:* Adolf Schaller





Holland Ford (Johns Hopkins University), et al., and NASA

The Hubble Space Telescope has imaged a gaseous disk (above) in the core of the giant elliptical galaxy M87. One side of the disk is highly blueshifted, meaning the gas is moving toward Earth at very high speed, while the other side is highly redshifted, meaning the gas is moving away from Earth at very high speed. The gas must be whipping around a central supermassive object — most likely a two-billion-solar-mass black hole. M87's black hole powers a humongous jet (right), a relic of the quasar epoch.

way around that obstacle. You might call it "quasar paleontology": the study of quasars by examining the fossils that presently surround us. "They're now old and dead," notes University of Michigan astronomer Douglas Richstone, "but we can still learn from them." The closest quasar fossil, a relatively quiescent black hole of some two million solar masses, resides smack dab in the center of our own Milky Way Galaxy. Indeed, astronomers are coming to believe that every major galaxy was a quasar in its youth. Quasar activity is likely a common phase in the life of a galaxy and not the exception, as once thought.

The search for quasar fossils began in the late 1970s. Caltech astronomers Peter Young and Wallace Sargent figured that if quasars had truly been powered by black holes, the remnants should be scattered all about us. To check, they peered into the center of M87, the giant elliptical galaxy that sits at the center of the great Virgo cluster of galaxies located some 50 million light-years away. As a prominent radio source, M87 was a good prospect. Young and Sargent soon claimed they found evidence for a three-billion-solar-mass black hole in M87's center. Other astronomers were skeptical.

But Young and Sargent's work was highly influential, for an important paradigm was at stake here. The most persuasive way to explain the tremendous energies spewing from quasars is a black-hole engine. Alternate sources of energy — supernova explosions, extreme star birth, and such — fall far short. "The success of the black-hole picture strongly motivated us to look for dead engines," says University of Hawaii astronomer John Kormendy. "But it's a tricky and dangerous subject. It's easy to talk yourself into believing that you've proved what you expect to find." The hunt was vigorously renewed ten years ago, especially as electronic instrumentation and telescopic resolution improved.

Richstone, noted for his modeling of stellar orbits within a galaxy, first got involved via a letter. Alan Dressler of the Carnegie Observatories sent him data on both M31, the nearby Andromeda Galaxy, and its smaller companion M32. Did the unusually rapid motions he was detecting within the Andromeda Galaxy's center, asked Dressler, suggest that stars were swiftly orbiting a supermassive black hole? Richstone concluded they did. The breakneck speeds were hard to explain if you assumed that the center was populated by a dense cluster of low-mass stars or stellar remnants, the only other viable alternatives.

Kormendy independently reached an identical conclusion. Both groups estimated that the Andromeda Galaxy harbored a black hole weighing about 30 million solar masses, while M32 had a black hole a tenth that size. Kormendy, the world's most prolific black-hole hunter, would go on to find half a dozen more quasar fossils in galaxies ranging out to the Virgo cluster. His telescope, the 3.6-meter Canada-France-Hawaii Telescope located atop Hawaii's Mauna Kea, provided him the superb seeing conditions he needed to carry out the painstaking measurements required in this line of work.

The technique for finding a massive black hole in a galaxy's center — at least indirectly — is based on fundamental laws of physics. Think of a satellite orbiting the Earth. If you measure the radius of the satellite's orbit and its speed, Newton's laws of gravity allow you to figure out Earth's mass. Similarly, by measuring a star's speed and orbital size within a galaxy, you can determine the mass inside the star's orbit. A black hole is suspected when astronomers see stars and gas zipping around extremely fast near the center; in many cases, only a supermassive black hole can keep such high-velocity stars from flying out of the galaxy.

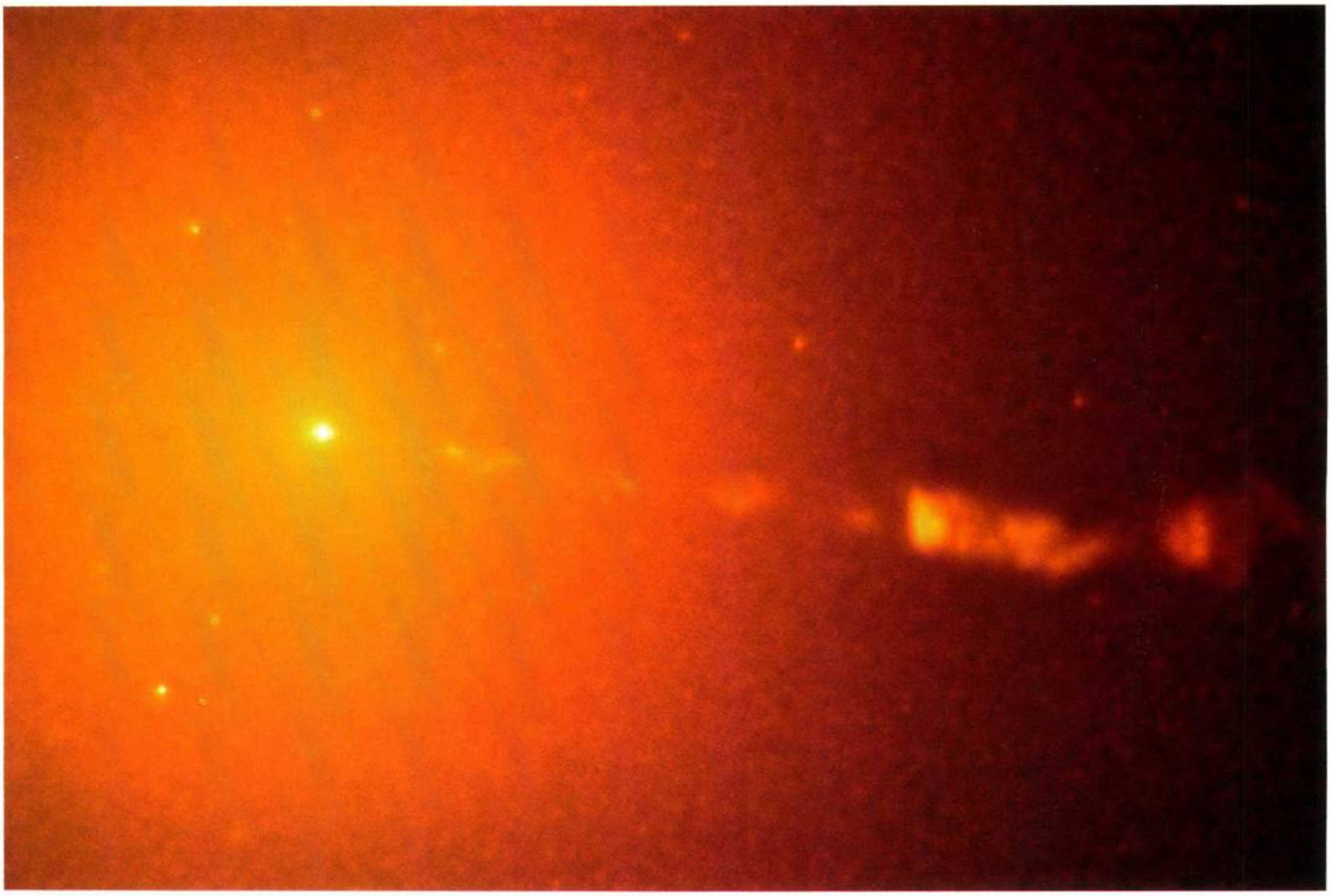
At first, black-hole hunters tackled the easiest cases: nearby spirals with disks seen edge-on, such as M104, the famous Sombrero Galaxy. Candidates need to be close by so astronomers can resolve the tiny region in the middle where the black hole affects the motions of the inner population of stars, about one percent of the mass of the galaxy. Edge-on is the best orientation to measure stellar orbital speeds, as one edge of the disk spins toward us, and the other spins away. Kormendy found a billion-solar-mass black hole within M104 in this way. Another good case is NGC 3115, which likely contains a two-billion-solar-mass monster.

Soon after the Hubble Space Telescope was repaired in 1993, many astronomers teamed up to continue their explorations from space. Since their targets were galactic nuclei, these Hubble observers soon nicknamed themselves the "nukers." Hubble speeded up the process and quickly added to the count. Indeed, every galaxy that Hubble has closely examined reveals a central black hole.

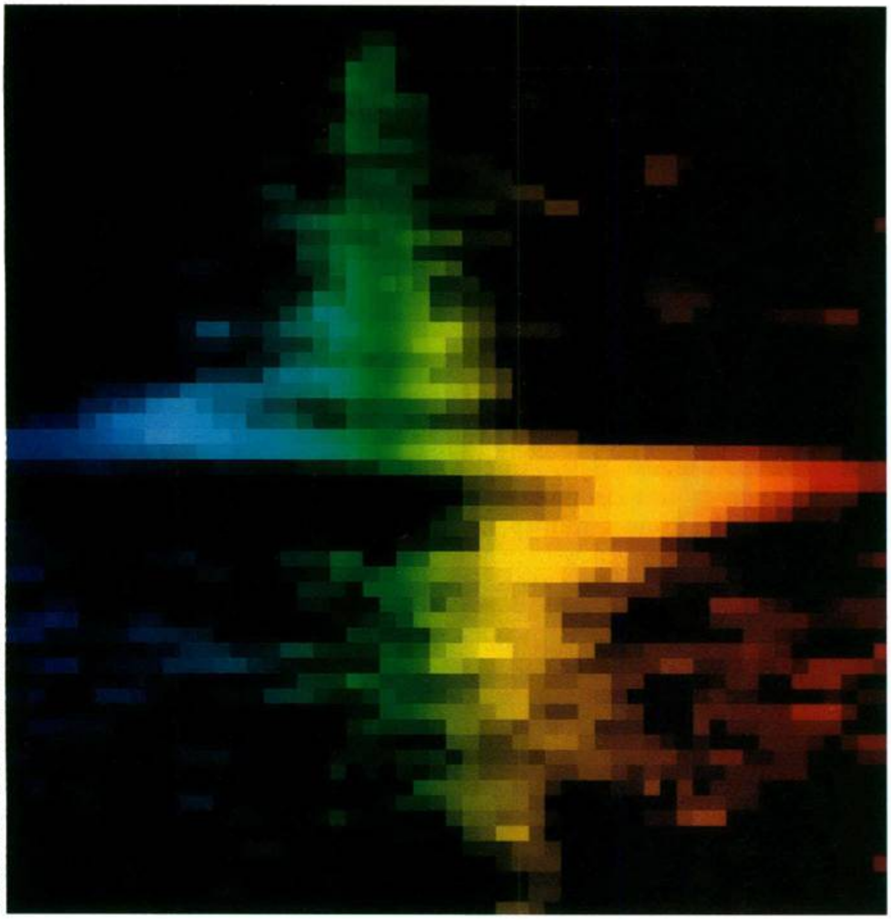
Such was the case for NGC 4261, a giant elliptical galaxy. By focusing Hubble on that target, Johns Hopkins astronomer Holland Ford and colleagues were able to vividly image an 800-light-year-wide disk of gas and dust that is likely fueling a black hole a billion times the mass of the sun. This case is particularly important because NGC 4261 is still active (although not at quasar levels). Enormous jets of radiation are emerging from the core. The galaxy's central black hole will probably be feeding on its "meal" for some 100 million years, a common lifetime for many active galaxy outbursts.

Another spinning gas disk was found by Hubble in M87, the original quasar fossil candidate. With a jet that is visible to both radio and optical telescopes, M87 is widely regarded as a former quasar that gently hums along. Along with NGC 3115, Kormendy believes it's one of the best cases for a quasar fossil so far.

Radio astronomers introduced the newest technique for hunting down quasar fossils. Using a network of radio telescopes that span the continent, they tracked the intense microwave signals emitted by water masers, vast clouds of water molecules whipping around the center of the dust-shrouded spiral galaxy M106. This opens up the opportunity to look into dusty galaxies that are opaque to optical telescopes.



Tod Lauer (NOAO), Sandra Faber (UCSC), and NASA



Gary Bower, Richard Green (NOAO), et al., and NASA

The Hubble Space Telescope's new STIS instrument catches the telltale signature of a monster black hole in the core of elliptical galaxy M84: a sharp zig-zag of blueshifted and redshifted gas. Gas just 25 light-years from the core is swirling around a central mass at 900,000 miles per hour, indicating a black hole of 1.5 billion solar masses.

All the differing techniques appear to be agreeing on the mass of the black holes in each galaxy. "That's very encouraging," says Kormendy. All in all, about 15 bona fide quasar fossils have been found so far; another two dozen are suspected from cruder measurements. "Ten years ago, if you found an object that you thought was a black hole in the center of a galaxy, half the field thought you were a little nuts," says Richstone. "I think that attitude was fair: Extraordinary claims demand a high level of proof. It was reasonable for people to be skeptical, but now we've gone from the simple discovery stage to carrying out surveys and demographics."

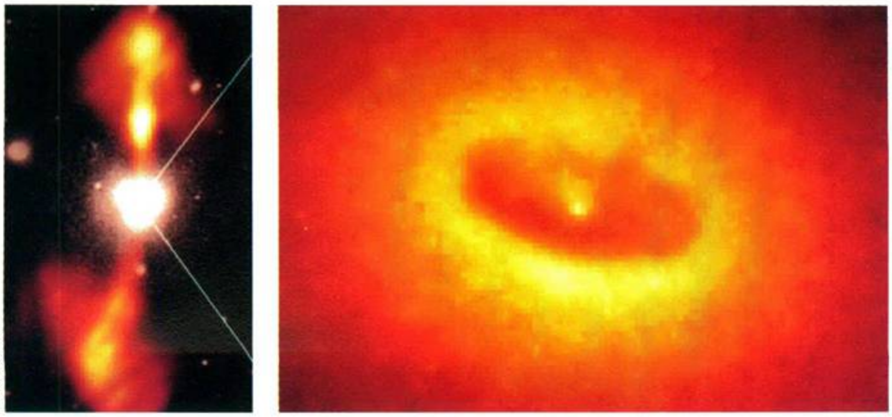
Working with Maarten Schmidt on several quasar surveys during the 1970s and 1980s, Richard Green had suspected that the quasar phenomenon was a short-lived episode in nearly all galaxies. "It's like a Roman candle — a burst of brightening for a relatively brief period," explains Green, now deputy director of the National Optical Astronomy Observatories in Tucson, Arizona. But it was also possible that only a fraction of all galaxies — a special breed — experienced an episode of quasar activity for a longer time. Now, though, the ever-expanding list of quasar fossils is encouraging astronomers to believe that Green's initial suspicion is correct: that nearly all major galaxies — spirals and ellipticals alike — harbor supermassive black holes, former quasar engines. With fossils littering the celestial sky, quasars now seem rather common.

"Now I want to know the exceptions," says Green. Kormendy has found at least one so far; spiral galaxy M33, a tiny neighbor of Andromeda, is devoid of a bulge and appears to have no supermassive black hole at its center, at least as observed so far. This suggests that supermassive black holes are connected to the presence of a bulge.

The more astronomers locate these fossils, the more they are able to discern patterns. Already, Kormendy and Richstone have discovered a fascinating rule: The greater the mass of the elliptical or spiral bulge, the larger its central black hole. "That's an astonishing fact," says Richstone. "Somehow, when the black hole forms, it knows what kind of galaxy it's in. Or when a galaxy forms, it knows what kind of black hole is in it." This seems to suggest that the formation of a galaxy and the growth of its central black hole are intimately linked in some as yet undetermined way. "It used to be only a theory — that black holes served as the 'engines' for quasar activity," says Kormendy. "But now we've established that black holes are indeed the engines and that they have masses as predicted."

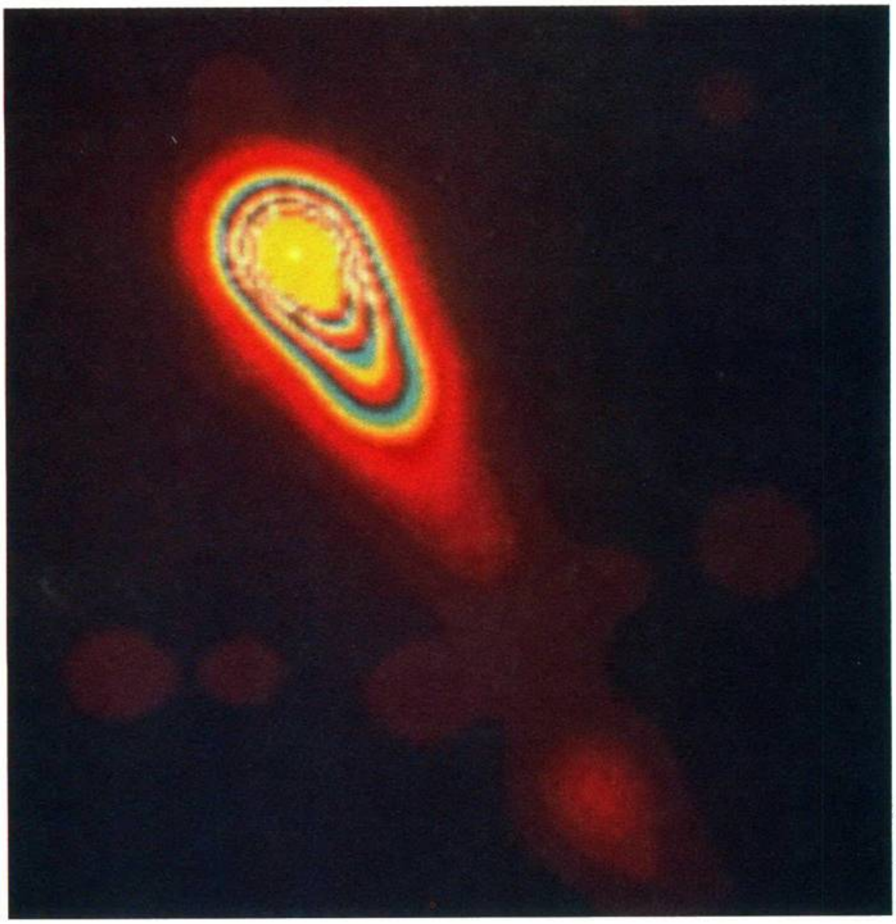
This is an exciting find because it offers a means of determining how these black holes formed in the first place. Perhaps the black holes formed first, serving as "seeds" around which

A ground-based optical and radio composite image (left) shows a jet streaming out of the center of elliptical galaxy NGC 4261. A Hubble image (right) shows a 400-light-year-wide disk in the galaxy's core. A 1.2-billion-solar-mass black hole presumably lies at the center.



NRAO/Caltech

Holland Ford (Johns Hopkins University), et al., and NASA



This radio image shows a powerful jet shooting out of the core of galaxy NGC 6251. Later Hubble Space Telescope observations strongly suggest this galaxy harbors a supermassive black hole.

Dayton Jones (JPL)

galaxies formed; over time, the black holes consumed the galaxies' stars and gas to enlarge themselves. Or perhaps there were smaller black holes, each in a galactic building block, that eventually merged to form a giant galaxy as well as a supermassive black hole. For now, there's not enough evidence to distinguish between the two scenarios.

Can astronomers truly be sure that these black holes are linked to past quasar activity? The numbers are tantalizingly suggestive. The density of galaxies with supermassive black holes observed here in our local surroundings just about matches the density of quasars seen in the far universe. "We can see the light emitted from quasars in the distant past, and we can estimate the density of quasar relics required in the present universe to make that light," says Richstone. "The answer turns out to be very close to the black holes we are discovering. It's that fact that makes us believe we're seeing the relics of old quasars."

But there's a major puzzle left to solve: Some of these galaxies seem to have lots of "food" remaining in their center. Why do they stay inactive in the midst of this cornucopia? "This could be embarrassing," reported Kormendy and Richstone in a review of the field. New theoretical studies, however, are suggesting that the disks of material actually remain quiet most of the time and only flare up when an instability occurs. Perhaps conditions for a runaway catastrophe — a quasar outburst — are best in the early universe, when the cosmos was smaller and when galaxies were young, gas-rich, and more liable to bump into one another.

An instrument called STIS (for Space Telescope Imaging Spectrograph), recently installed on Hubble, will surely accelerate the discovery of more fossils. One of its first measurements showed its astounding abilities. As soon as it was operative in January 1997, according to STIS team member Green, NASA officials told them to "go find us a new black hole." "And we aimed to please," jokes Green.

Gary Bower, Green's colleague at the NOAO, had already been studying M84, an elliptical galaxy with shadowy dust lanes, perhaps the remnant of a galaxy recently gobbled up. It was a promising subject but awkwardly placed in the sky. The astronomers had only one good guide star to keep Hubble steady. Nevertheless, the data on M84's inner core, originally gathered to check that STIS was in working order, revealed stunning science.

The spectrum, a colorful "zigzag," is a compelling signature of a black hole. "We first see a very slow rotation in an outer, larger gas structure," explains Green. "Then, suddenly, as we approach the center, the gas velocities go faster and faster and faster. Right in the center, there's a huge spread. The top velocity is 400 kilometers per second, very fast for material in a stable orbit within 25 light-years of the galaxy's center." This implies that within that disk lies a gigantic black hole containing the mass of 1.5 billion suns.

Black-hole hunters have been eagerly anticipating STIS. It can carry out a detection 40 times faster than an earlier Hubble instrument, the Faint Object Spectrograph. The FOS had to take data spot by spot, slowly building up a complete sample across the galactic center. STIS does it in one fell swoop. The nukers will soon use STIS to examine ten more galaxies, all good fossil candidates. "We're now in high gear," says Kormendy. With STIS in place, new finds will likely arrive fast and furiously. In the past, Kormendy has spent a full year piecing together the model for just one galaxy. "But we now have a level of confidence we didn't dare have before," he says.

Black holes, once a theoretical curiosity, seem to be central features in every large galaxy in the universe. No longer oddities, they may be the natural result of galactic evolution and perhaps engines for tremendous fireworks displays that announce each galaxy's birth. "I showed our work to a stellar astronomer, a former black-hole doubting Thomas," notes Green, "and she said, 'I guess I'm going to have to start believing in this.'"

Award-winning science writer Marcia Bartusiak is a member of Astronomy's *editorial advisory board. Her last article was "Cosmic Jekyll & Hyde" in the May 1998 issue.*

TO THE EDGE OF SPACE

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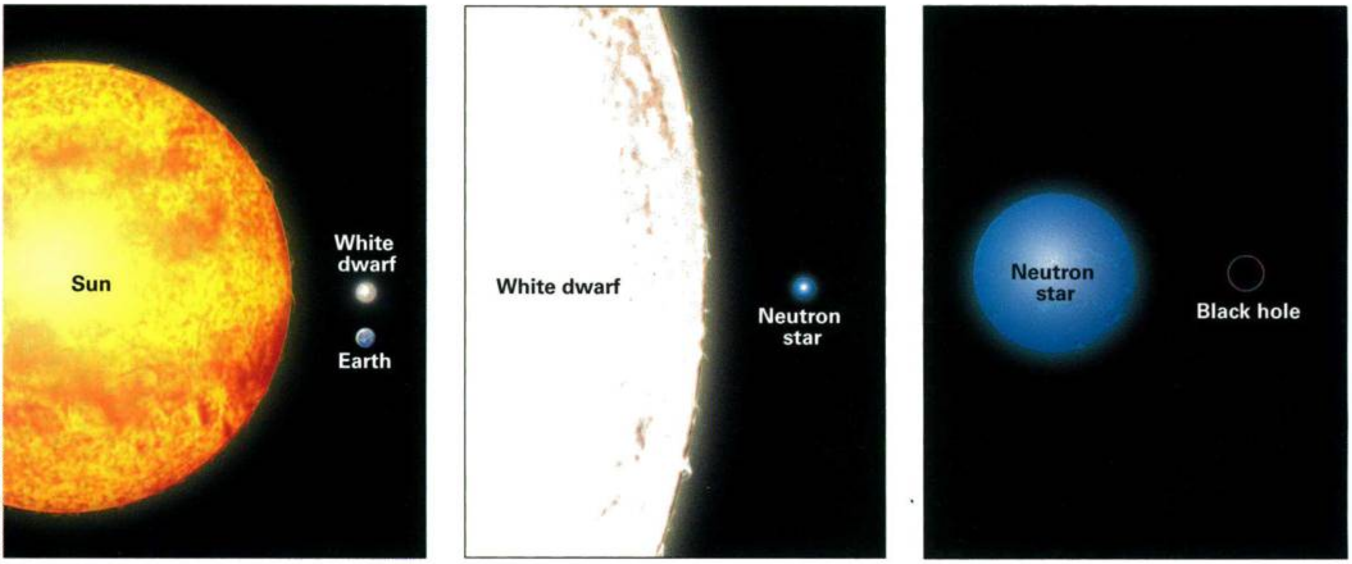
AND TIME

Cosmic enigmas no more, black holes are places where gravity has grown so strong that not even light can escape. by Martin Rees

Gravity is the most ubiquitous force in the universe. Everything experiences gravity, whether it's the pull that keeps our feet firmly on the ground or the overwhelming force that keeps our planet in orbit around the sun.

But the gravity we feel in the solar system is a far cry from what exists in some other parts of the cosmos. Because gravity increases with the mass of an object, heavy objects exert more pull. And gravity grows stronger the closer you get to an object, so objects with small diameters wield greater force. That's why white dwarfs — collapsed stars with a



Astronomy: Elisabeth Rowan

An Earth-sized white dwarf may seem tiny compared with the sun, but it dwarfs the much smaller neutron stars and black holes.

mass about that of the sun packed into a sphere the size of Earth — exert such strong gravity. But neutron stars go even further, typically packing more than a sun's worth of material into an object the size of a city.

Gravity may be strong in neutron stars, but there are other objects where it is even more overwhelming. These are black holes — bodies that have collapsed so far that no light, nor any other signal, can escape from them. They are expected in many theories of gravity, not just Einstein's general relativity. Indeed they were in essence conjectured more than 200 years ago. In 1783 John Michell presented a paper to the Royal Society of London about how gravity might affect light. He was an underappreciated polymath, a clergyman who also studied experimental physics and binary stars.

Michell noted that an object thrown from the surface of the sun would need a speed about 1/500 that of light if it were to escape. He realized also that the escape velocity (as we would now call it) would be much larger for a body heavier than the sun — in fact a simple calculation based on Newtonian gravity shows that the escape velocity for bodies of a given density is directly proportional to their radius. Therefore, he said: "If the semi-diameter of a sphere of the same density as the sun were to exceed that of the sun in the proportion of five hundred to one, and supposing light to be attracted by the same force in proportion to its *vis inertiae* with other bodies, all light emitted from such a body would be made to return toward it, by its own proper gravity."

So Michell was suggesting that the most massive objects might be undetectable by their direct radiation but may still manifest gravitational effects on material near them.

Pierre Laplace advanced the same idea in 1794, in his book *Le Système du Monde*. He deleted this passage from later editions, though it's not clear why — probably he had, in the meantime, lost confidence in an argument that envisaged light as "ballistic" particles.

Newton's theory doesn't work when the motions induced by gravity near the speed of light. But general relativity copes quite consistently with situations when gravity is overwhelmingly strong, as it is in black holes — indeed it is there that Einstein's equations have their most remarkable consequences.

EINSTEIN'S BLACK HOLES

In 1916, less than one year after Einstein announced his theory, the German astronomer Karl Schwarzschild applied it to calculate how gravity behaved around a spherical mass. Einstein had already worked out how light would be deflected near the sun, but this required only an approximate calculation because gravity in the solar system is weak enough that the bending is small. He knew his equations were hard to solve exactly and was therefore quite enthusiastic that Schwarzschild had found this solution. Schwarzschild died shortly afterward, from a rare metabolic disorder that he contracted while serving as a lieutenant of artillery in the German army.

Schwarzschild did his calculations more than 50 years before neutron stars were discovered. These were the first objects found with gravity strong enough to reveal the distinctive features of Einstein's theory. The passage of time is distorted: A clock on a neutron star's surface would seem to a distant observer to be ticking more slowly. Associated with this is the gravitational redshift: Radiation from the surface reaches distant observers with a longer wavelength. These effects may be as large as 30 percent on the surface of a neutron star.

What would happen if a neutron star contracted further or more mass were squeezed into the same radius? Gravity would then become so strong that not even light could escape its pull. The minimum radius from which light could escape happens — though this is little more than a coincidence — to be exactly equal to what Michell calculated. At this "Schwarzschild radius" the gravitational redshift is infinite. It is, in effect, a horizon shrouding the interior from view, a semipermeable membrane that can be crossed only in the inward direction.

Light rays near a black hole are even more strongly curved than around a neutron star. An experimenter situated just outside the horizon would need to aim a beam of light almost exactly radially in order for it not to be bent back and eventually swallowed by the black hole. No astronaut who ventured within the horizon could send *any* light signals to the external world — it is as though space itself is being sucked inward faster than light moves out through it. An external observer would never witness the astronaut's final fate: Any clock would appear to run slower as it fell inward, so the astronaut would appear impaled at the horizon, frozen in time.

The Russian theorists Yakov Zeldovich and I. D. Novikov, who studied how time gets distorted in the vicinity of collapsed objects, coined the term frozen stars. The term black hole was not coined until 1968, when the American physicist John Wheeler described how an infalling object "becomes dimmer millisecond by millisecond . . . light and particles incident from outside . . . go down the black hole only to add to its mass and increase its gravitational attraction."

The Schwarzschild solution is too special to apply to real objects, however, because most things in our universe spin and consequently are not spherical. In 1963 the New Zealander Roy Kerr discovered a more general solution of Einstein's equations, which represented a collapsed *rotating* object. As in the Schwarzschild case, a horizon shrouds the exotic interior from view. But the space behaves like a vortex: Objects are forced to swirl around as well as (if they get too close) fall inexorably inward.

The hole's interior cannot be observed from a safe distance. One's Faustian urge must be sufficiently strong to venture inside. What would happen? An infalling astronaut would experience stronger and stronger tidal forces (the difference between the gravitational acceleration on the head and feet); these forces diverge toward infinity within a finite amount of time as measured by a clock falling with the astronaut.

In a Schwarzschild black hole, the rising tidal forces would alternately stretch and squeeze the astronaut with ever-increasing frequency and intensity. In a spinning hole the stresses become infinite on a ring rather than at a point. Kerr immediately realized that this offered even more remarkable prospects. He excitedly told a colleague at the time, "Pass through this magic ring and — presto — you're in a completely different universe where radius and mass are negative!"

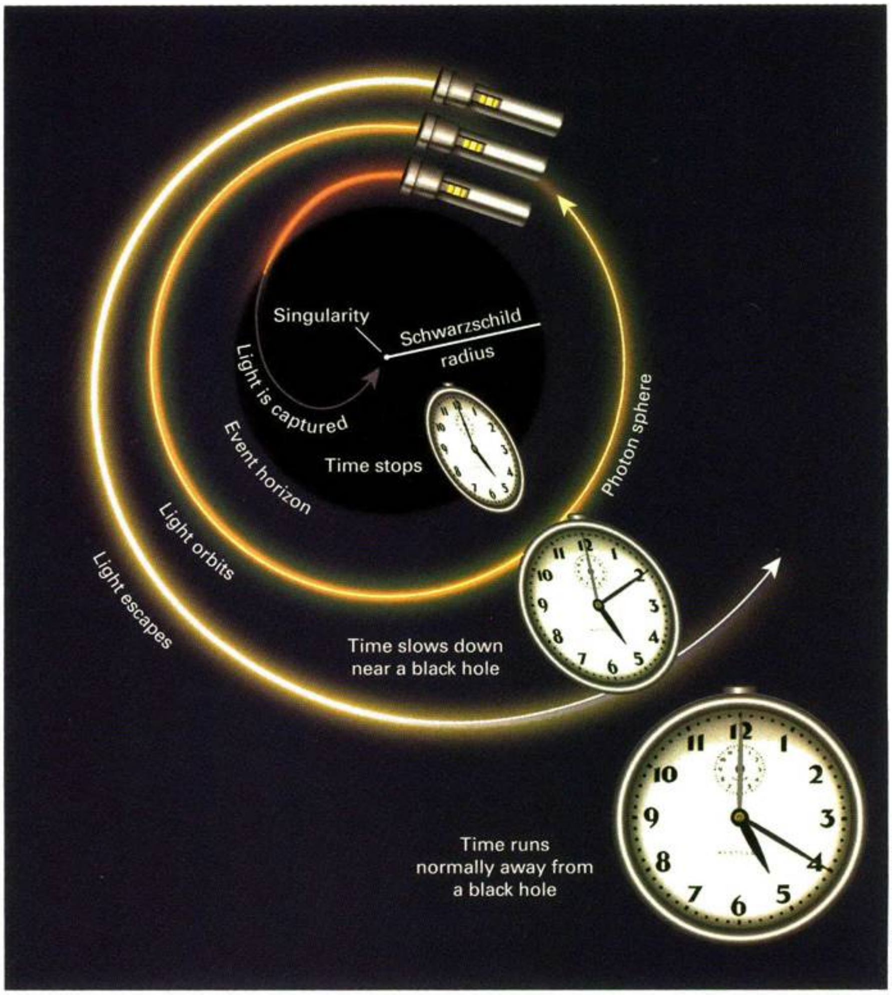
OUTSIDE THE HOLE

In the 1960s it wasn't clear whether the Schwarzschild and Kerr solutions described a typical black hole or whether they were idealized and atypical holes that theorists had stumbled upon simply because they were the ones for which Einstein's equations could be most readily solved. We now know that there cannot be any other kind of black hole. This realization is crucial for our understanding of the real universe. Viewed from outside, black holes are exactly standardized objects — no traces persist to distinguish how a particular hole formed or what kind of objects it swallowed. The combined efforts of several theorists had proved this result by the early 1970s.

Kerr's solution, when first discovered, seemed to describe a special and atypically symmetric situation. But it acquired paramount importance when theorists realized that it described space-time around *any* black hole. A collapsing object quickly settles down to a standardized stationary state characterized by just two numbers: one that measures its mass and one its spin. (In principle, electric charge is a third such number, but stars never have enough electric charge for this to be relevant to a real collapse.)

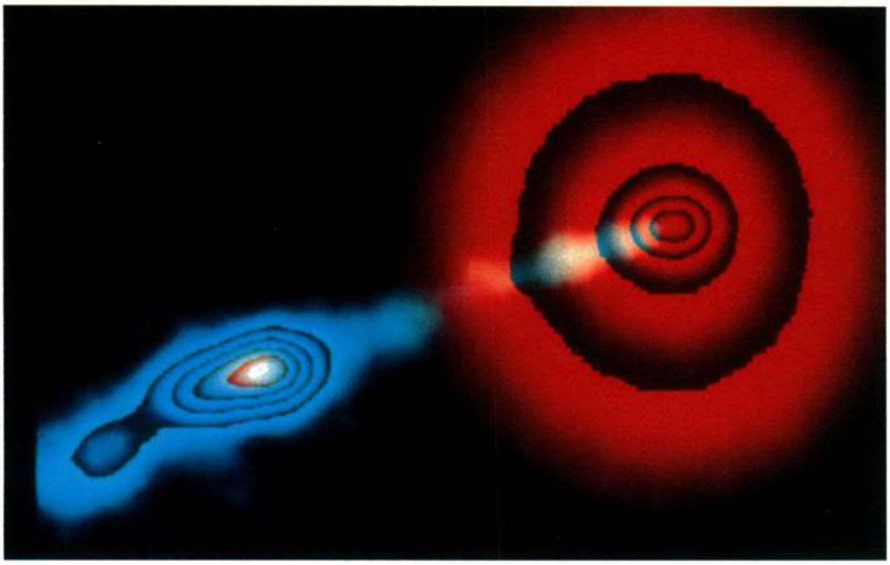
Black holes are the "ghosts" of dead massive stars; they have collapsed, cutting themselves off from the rest of our universe but leaving a gravitational imprint frozen in the space they have left. Around black holes, space and time behave in highly non-intuitive ways. For instance, time stands still at the surface: An observer hovering there would witness the whole future of the external universe in what, subjectively, seemed quite a short period.

To the physicist, gravitational collapse is important because entirely new concepts are needed to understand what is going on. The paradoxes within a black hole are as fundamental, and as far-reaching in their implications, as the puzzles that confronted Einstein's contemporaries at the beginning of the 20th century and triggered the development of relativity and the quantum theory. Black holes preclude space and



Astronomy: Elisabeth Rowan

As you approach a black hole, time slows down and light gets trapped. Anything that ventures inside the event horizon will be crushed out of existence at the singularity.



Smithsonian Astrophysical Observatory

The galaxy M87 (shown in red) harbors a black hole of three billion solar masses that beams a high-speed jet of electrons (blue).

time being a seamless continuum. They could even be gateways to other spacetimes sprouting from our own. The existence of black holes not only allows, but may even require, a broadening cosmic perspective that envisions our universe — everything astronomers might actually see — as just a member of an ensemble.

DEATH OF A STAR

But should black holes really exist? For more than 60 years, we've had good reasons for saying yes. In 1930, a precocious young Indian, Subrahmanyan Chandrasekhar, enrolled at Cambridge University, where he hoped to become one of Arthur Eddington's students. During the long voyage to England, he thought about white dwarfs — the dense remnants of stars that can no longer draw on nuclear energy. He reached a startling conclusion: White dwarfs more than 1.4 times as heavy as the sun couldn't exist — their central pressure could never build up high enough to counteract gravity.

This raised the question as to what happens when heavier stars run out of fuel. They may, during the course of their evolution, throw off so much material that their masses end up below Chandrasekhar's limit for a white dwarf. The outer layers may be expelled in a supernova explosion, leaving a neutron star, as seems to have happened in the Crab Nebula. But there is also a limit to how heavy a neutron star can be. Although this limit is less definite than that for a white dwarf because it depends on not-well-understood physics of how material behaves when squeezed to several times the density of an atomic nucleus, it almost certainly lies below three solar masses.

Stars don't all have the "prescience" to shed enough gas to bring them safely below this limit, and any stellar remnant more massive than three or so solar masses would collapse completely when its nuclear energy ran out. Astronomers think the supernovae triggered by the heaviest stars, those above 20 solar masses, leave black holes rather than neutron stars. Some massive stars may even collapse into black holes without producing any conspicuous supernova-type explosion. So the galaxy should contain large numbers of gravitationally collapsed bodies. How can we find them?

Once formed, black holes are essentially passive and the best hope of locating them lies in discerning their gravitational effects on neighboring stars or gas. Among the first to consider this was Zeldovich. He has a prominent place in modern cosmology, not only through his individual contributions but because, from the 1960s onward, his research school in Moscow spearheaded so many key discoveries, even though cosmology and relativity previously had been ideologically tainted in the Soviet Union.

Zeldovich was one of the last polymaths of physics — earlier in his career he had worked on particle physics, gas dynamics, and other fields, despite being preoccupied for many years with the Soviet H-bomb project. Zeldovich was trained as a technician, bypassing traditional higher education, and originally specialized in chemistry. He attributed his lack of early interest in physics to ultra-traditional schooling: His teacher read out Newton's laws first in Latin, and only afterward in Russian.

Zeldovich realized that a black hole in close orbit around a star would accrete gas from its companion. Captured gas would swirl downward toward the black hole, orbiting faster and faster as it got closer. Compression and viscous friction would make it so hot that it would radiate intense x rays. If the inflow were turbulent and unsteady, the x-ray intensity would flicker irregularly.

X-ray observations highlight the most energetic features of the universe — the hottest gases, the strongest gravity, the most energetic explosions. Spinning neutron stars accreting from binary companions were among the first x-ray sources discovered. Cygnus X-1 is an x-ray source orbiting a binary companion, but it differs from the accreting neutron stars in that its x rays vary erratically rather than with a regular period. Moreover, it weighs at least six solar masses, implying that it cannot be a neutron star or white dwarf. There are now several other black-hole candidates in our galaxy at least as convincing as Cygnus X-1. These all have binary companions — ordinary stars orbiting around them from which gas is being sucked inward toward the hole. They are all too heavy to be neutron stars; the rapid and irregular way their x-ray output varies fits with the black-hole hypothesis.

The case still isn't completely watertight: Ad hoc interpretations that do not involve a black hole can always be devised. One's assessment of the odds obviously depends on whether one regards black holes as inherently absurd or as plausible endpoints for stellar evolution. The alternative explanations are generally too contrived to be convincing: As the physicist Edwin Salpeter puts it, "A black hole in Cygnus X-1 is the most *conservative* hypothesis."

THE BIGGEST BLACK HOLES

The black holes I have discussed so far represent the final evolutionary state of stars and have radii of 5 to 30 miles (10 to 50 km). But vastly larger black holes exist beyond our galaxy. The evidence for these, though more recent, is now even more compelling than for anything in our own galaxy.

In the centers of some galaxies, gas and stars are swirling into a black hole weighing as much as millions, or even billions, of suns. They manifest themselves as quasars or as intense sources of cosmic radio emission. These black holes, each with diameters as large as the solar system, are regions that have already experienced the fate that will engulf everything if our universe eventually collapses.

When its external supply of fuel ceases, a quasar switches off. The best guesses about quasar demography — their number, their lifetime, and how many generations have lived and died — suggest that most galaxies went through a quasar phase and may therefore contain relic black holes lurking in their centers.

Even a quiescent black hole — a dead quasar — still exerts a gravitational pull on its surroundings, and there would be two telltale signs of its presence in the center of a galaxy. The first is simply a central "blip" in the light from the galaxy because stars are being pulled close to the hole. A second signature would be evidence that stars or gas clouds near the center are moving anomalously fast.

Nearby galaxies obviously offer the best prospects for finding such effects. A giant galaxy called M87 in the Virgo Cluster of galaxies harbors a central dark mass of about three billion suns. This monster black hole would be bigger than the entire solar system, Neptune and Pluto included. Another convincing case involves the Milky Way's nearest large neighbor in space, the Andromeda Galaxy. Its central hole weighs about 30 million solar masses. Black holes exceeding a billion solar masses are so big that they could swallow a star in one piece; a star falling toward a somewhat smaller hole would be shredded apart first, creating a more conspicuous pyrotechnic display.

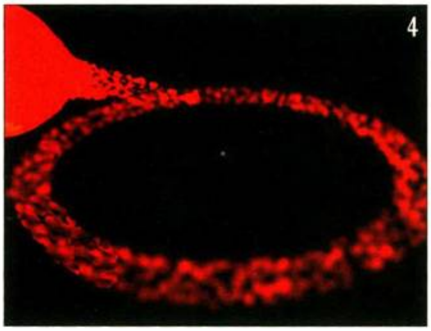
The most convincing evidence for a supermassive black hole comes from the work of radio astronomers, who used a special technique (linking radio telescopes spread across an entire continent) to map the center of a nearby galaxy, M106, in 100 times more detail than even the Hubble Space Telescope could achieve. They discovered a disk of gas orbiting exactly in the way expected if there is a central black hole of 36 million suns.

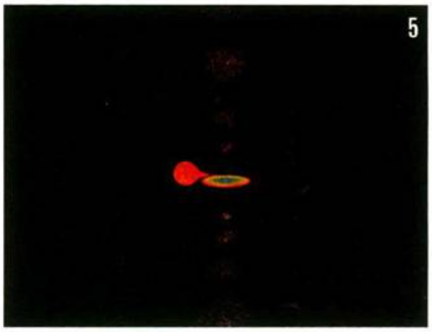
If there were indeed black holes in most nearby galaxies, our own galaxy would seem underendowed if it didn't harbor one as well. The motions of stars and gas around the center of our galaxy suggest a mass of three million suns — 10 times lower than the Andromeda Galaxy. With such a small black hole, our galaxy could never have hosted a powerful quasar.

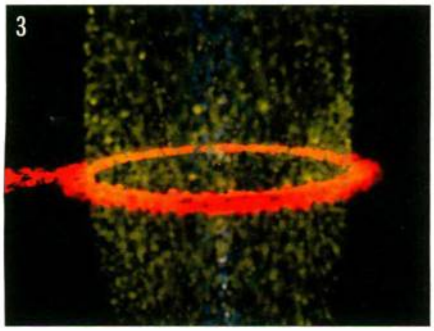
Objects like Cygnus X-1 and the centers of galaxies are places where the space of our universe gets punctured by the accumulation and collapse of large masses — collapse to entities described exactly by fairly simple formulae. As the English relativist Roger Penrose has remarked, "Is it ironic that the astrophysical object which is strangest and least familiar, the black hole, should be the one for which our theoretical picture is most complete." ■

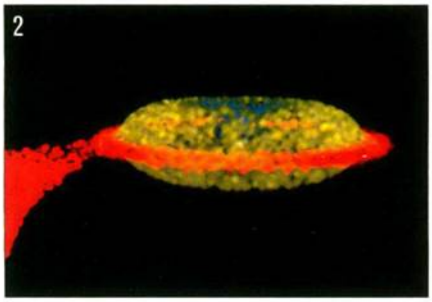
Sir Martin Rees, Britain's Astronomer Royal, is Royal Society Professor at King's College, the University of Cambridge.

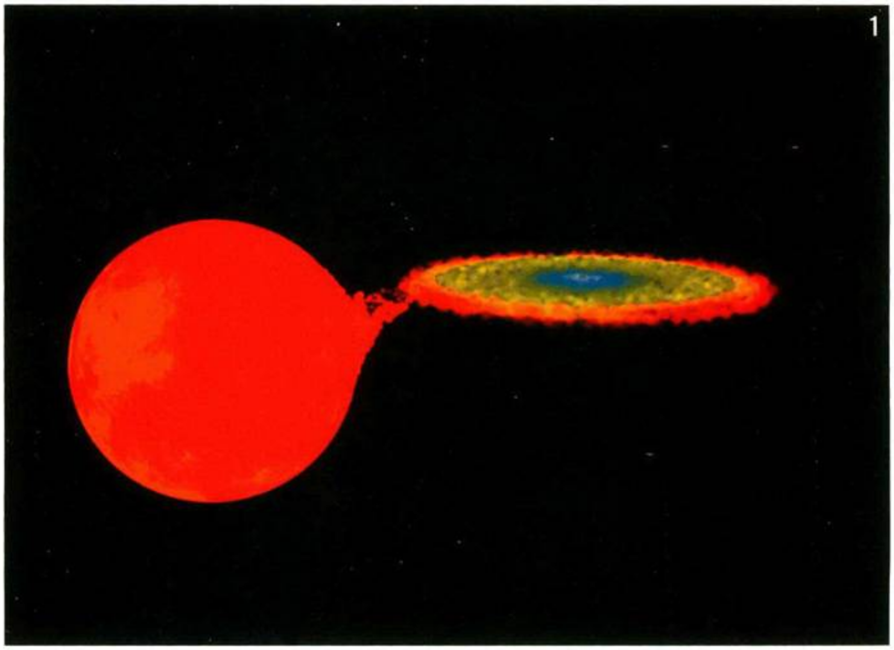
GRS 1915+105 is a probable black hole in our galaxy. In this simulation, the hole pulls material from a companion into an accretion disk (1). Once enough mass builds up (2), the inner disk is ejected into twin jets (3), clearing the inner region (4). The process then starts anew (5).





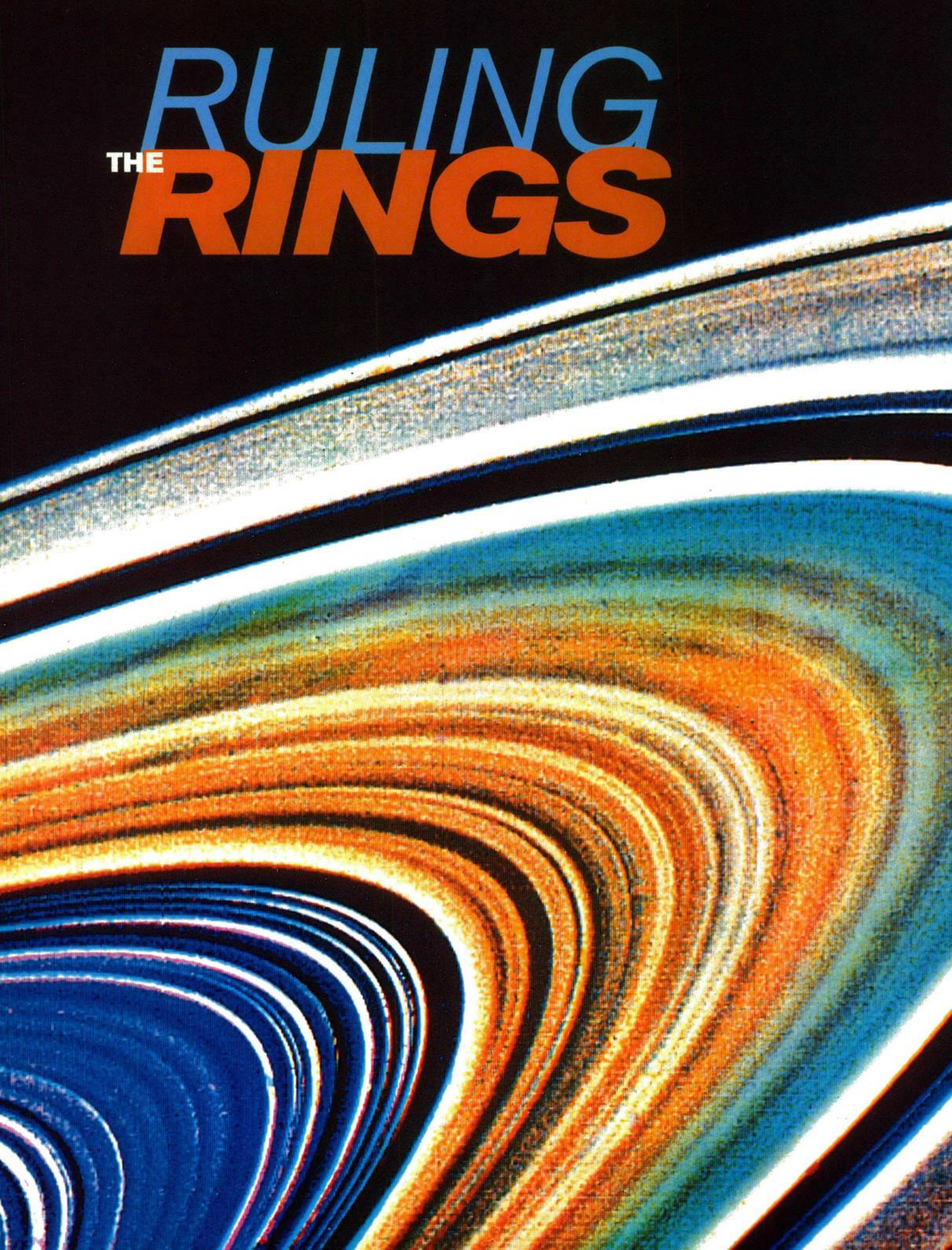


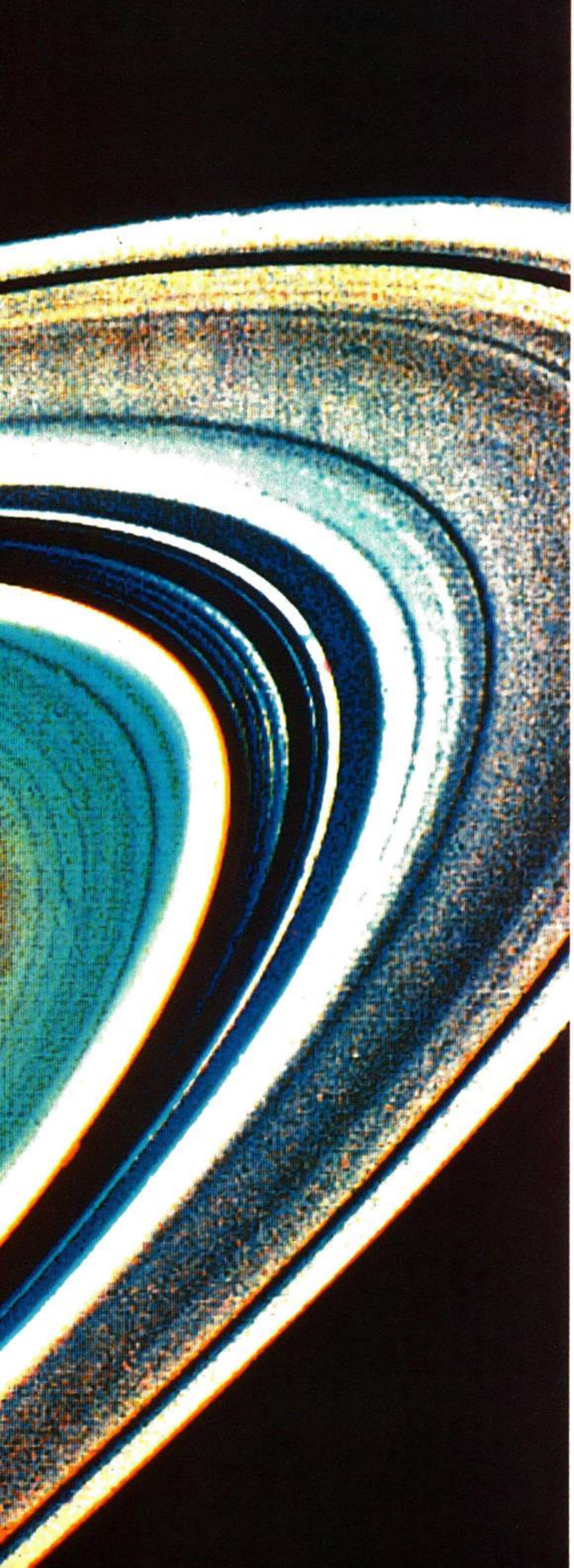




NASA

RULING THE RINGS





Planetary rings appear permanent, but they decay in less than 100 million years unless they are replenished.

by Neil F. Comins

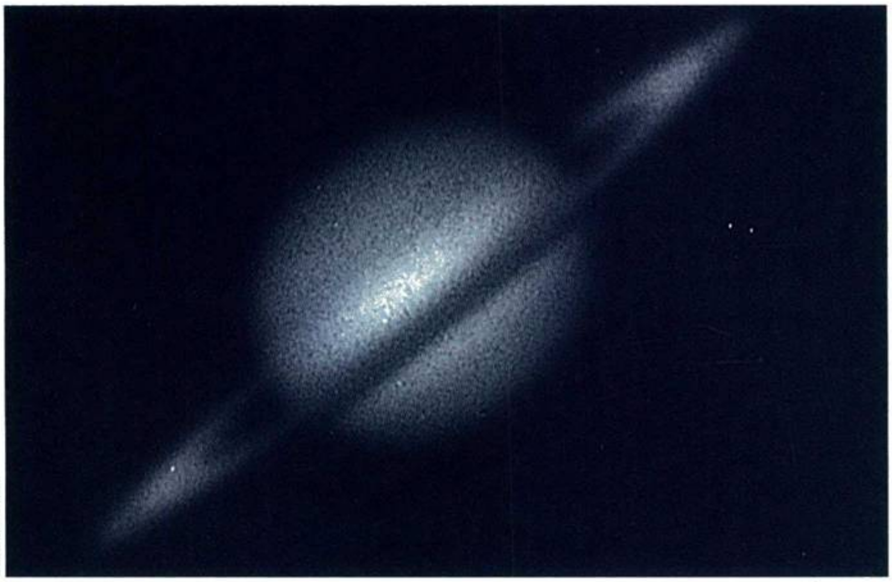
My grade school teachers in the early 1960s were definitive: Saturn was the only planet with rings. Indeed, photographs in those days revealed two or three rings around Saturn that looked as solid as sidewalk concrete. All the other planets looked bare. But my teachers missed the subtle point that just because rings around other planets hadn't been discovered didn't "prove" that they didn't exist.

Oh, how grade school has changed. Thanks to space exploration, better ground observatories, and space-based telescopes like the Hubble Space Telescope, students now learn that Saturn has some 3,000 rings. In fact, rings of various sizes, shapes, and compositions swirl around all four of the solar system's giants — Saturn, Jupiter, Uranus, and Neptune. Unfortunately none of these planetary rings are the least bit solid and would make for lousy skateboarding. Sorry kids. However, planetary rings offer students of all ages a chance to understand how basic physics operates to create, shape, and disperse rings in unexpected ways.

Saturn's bright rings are made up of fragments as small as dust motes and as large as 164 feet (50 m) across. The debris is made of ice or rocks that are covered with ice. NASA/JPL

Galileo discovered Saturn's rings in 1610. His telescope had such poor optics that he can't be blamed for interpreting the rings as part of a triple system: Saturn at the center and two smaller "bodies" on each side. Using a slightly better telescope than Galileo's, the Dutch astronomer Christiaan Huygens discovered in 1659 that the two smaller bodies were actually a ring. Huygens described it as a single smooth ribbon.

French-Italian astronomer Giovanni Cassini observed the first feature in the rings — a dark gap now called Cassini's division. Saturn was visible through this division, suggestive evidence that the rings are not solid. By the first half of the 19th century observers had seen three concentric rings containing several divisions, and astronomers struggled to explain what they were.



David J. Pontzer

Saturn's rings as they appeared to Galileo.

A century before the Pioneer 11 spacecraft showed in 1979 that the rings were composed of innumerable pieces, scientists had established that the rings could not be solid. Indeed, there was neither a way that a solid ring could assemble, nor any way to hold one together even if a giant paving machine could produce one.

LAWS OF THE RINGS

Large objects like planets and moons coalesce from smaller pieces, which in turn coalesce from even smaller pieces. Presumably, by analogy, if a solid ring could form, it also would coalesce from smaller pieces. However, the laws of physics prevent such joining.

Consider, for example, two mountain-sized pieces of space debris orbiting Saturn in the same plane and in the same direction, but at slightly different distances from the planet. According to Newton's law of gravity, the inner body would move around the planet faster than the outer body. Imagine standing on the outer body, watching the inner one pass between you and the planet. As this inner satellite approaches, it attracts your object more and more strongly. However, something unexpected occurs. As the faster moving satellite passes between you and the planet. It pulls your satellite forward and actually gives it more energy than it started with. As a result of the increased energy, your satellite spirals outward beyond its original orbit, rather than spiraling inward and eventually joining the inner body.

In order to conserve the total energy and momentum of the system, when your satellite moves away from the planet, the faster-moving satellite slows down and drifts inward. The two objects seem to repel each other, thereby preventing a solid ring from coalescing.

Suppose that the rings around Saturn we see from Earth had somehow formed a single, solid ring. Let's say it is one vast roller-blading track 48,000 miles (77,000 km) wide (from inner edge to outer edge) and hundreds of feet thick, and it is held together primarily by gravity and molecular forces. Would the track stay intact? Unfortunately, no. In the first place, it would be pummeled and fractured by asteroids, comets, and other debris. In addition, each impact would generate waves on the solid ring, like the ripples created by a rock tossed into a pond, that would fracture the ring.

The gravitational tugs from Saturn's moons also would warp a solid ring. There's more. Electric currents created by cosmic rays, radiation from the sun, and Saturn's magnetic fields would heat, warp, and rip the rings.

Saturn's gravity adds to those discombobulating forces. This gravitational effect is particularly important. Imagine a solid ring held together by gravity, like a hula hoop, orbiting rigidly at the high speed necessary to maintain it at a fixed distance from Saturn. Because gravitational forces decrease rapidly with distance by the so-called inverse-square law, the gravitational force from Saturn pulls more strongly on the inner side of the ring than on its middle or outer parts. This is a more powerful version of the tidal force created by the moon and sun on Earth.

The net effect of all the forces is this: A solid ring would erode into smaller and smaller fragments and the content of these fragments would stretch into a wide band.

If the rings of Saturn aren't solid, what are they?

Physicist James Clerk Maxwell first proposed in 1857 that the rings are made up of countless small pieces. In 1980 and 1981, the Voyager 1 and 2 spacecraft confirmed his predictions. The spacecraft flew within 310,000 miles (500,000 km) of the rings and showed that those visible from Earth actually are composed of thousands of ringlets, each only a few miles wide. The Voyagers also photographed rings that were too thin or too dark to be seen easily from Earth.

The spacecraft also found dark "spokes" in the rings that dissipate, only to reform. These spokes are believed to form when charged dust particles are drawn out of the ring disk by Saturn's magnetic fields.

Ringlets vary in brightnesses because each is a different size and has different compositions. Brighter rings are made mostly of ice or rock covered with ice. The particles are as small as sand grains and as large as 160 feet (50 m).

Larger pieces scatter light backwards, while sand-sized particles scatter light forward, an effect similar to the glow of frost on a car windshield at sunrise. Looking at the rings from the sun's side, as we always do from Earth, such tiny particles are almost invisible. They were discovered by the Voyager 1 spacecraft when it passed beyond Saturn, turned back, and took pictures with the sun in the background. Cassini's division, which looks empty from Earth, glowed brightly due to forward-scattering particles.

DIM RINGS OF URANUS

Uranus's rings were discovered accidentally in 1977 by James Elliot. He was viewing a faint star from the Kuiper Airborne Observatory and observed that it disappeared as it neared Uranus — a phenomenon called occultation.

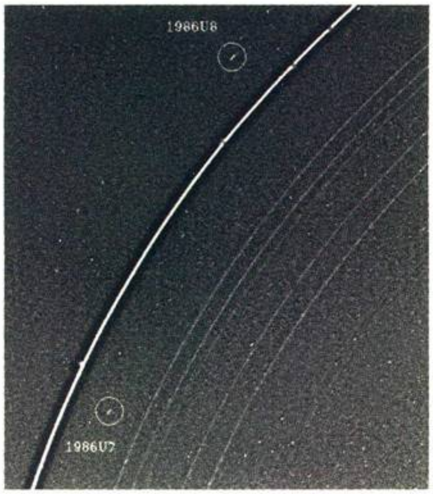
Astronomers can learn a lot about planets' rings by analyzing occultations. The components of Uranus's 11 rings range from dust and pebble-sized chips to hunks 30 feet (10 m) across.

Uranus's rings are much narrower than Saturn's, and the total mass of Uranus's rings is only 1/10,000 the mass of Saturn's rings. Furthermore, Uranus's rings are made of dark, rocky material that scatters less than 5 percent of the light striking it. Saturn's rings scatter about 60 percent. Little wonder, then, that Uranus's rings were only recently discovered.

Jupiter's ring system was discovered in 1979 by the Voyager 1 spacecraft. The giant planet's ring material is dark and rocky like that of Uranus. It is divided into three major segments: the 14,250-mile-wide (23,000 km) inner halo, the 3,970-mile-wide (6,400 km) main ring, and the outer gossamer ring, which is 52,700 miles (85,000 km) wide but has only 0.000001 percent of the mass of the other two rings.

Jupiter's rings are sparse because they are being drawn by magnetic fields into the planet. Meteorites that strike the tiny moons Metis and Adrastea are thought to help replenish the rings by ejecting material from the moons into the rings. In the same way, Enceladus is apparently resupplying Saturn's tenuous, outer E-ring.

Using stellar occultations, ring arcs around Neptune were observed from ground-based telescopes beginning in 1984. However, complete rings were first seen unambiguously in 1989 by Voyager 2. Neptune's four known rings are composed of microscopic pieces of matter. Small amounts of dust separate the rings, each of which is dark and contains internal structure. Except for the third ring out, the 3,600-mile-wide (5,800 km) Plateau ring, Neptune's rings are all less than 30 miles (50 km) wide and contain about a millionth the mass of Saturn's rings. The outermost Adams ring is clumpy, but the cause of the clumpiness is not yet known.



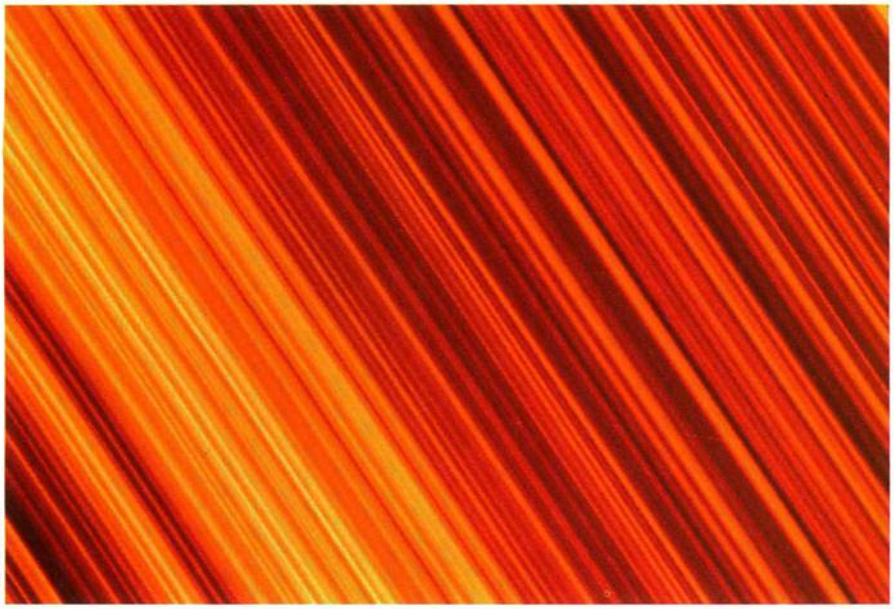
JPL, Caltech, NASA

Voyager 2 discovered these two "shepherd" satellites associated with the rings of Uranus.

SHEPHERD SATELLITES

Planetary rings, especially thin ones, are unstable. Under the influences of impacts from other matter, their planet's gravitational and magnetic forces, and the drag from planetary atmospheres, inner rings are pulled into the planet, while outer ones drift away. Unless rings are replenished or stabilized, they typically dissipate in less than 100 million years. Fortunately, there are both ring-replenishing and ring-stabilizing influences at work in the solar system.

This false-color slice of Uranus's epsilon ring taken by Voyager 2 enhances the small-scale structure of the ring. Reddish areas contain less material and yellow areas contain more material.



NASA and JPL

Impacts on moons may replenish adjacent rings. Stabilizing is done by the gravitational attraction of pairs of small moons, called shepherd satellites. Each pair of shepherd moons helps keep its ring in place: An inner shepherd pushes its ring outward, while an outer shepherd pushes its ring inward.

Most moons in our solar system orbit in the direction that their planets rotate and drift slowly outward. Triton is contrary. It orbits Neptune in the opposite direction, which means that Neptune's tides will slow it and cause it to slowly spiral toward the planet. Triton will eventually fall below something called its Roche limit, the distance from a planet at which the tidal and rotational forces acting on the satellite would tend to disrupt it. The 1,677-mile-wide (2,705 km) moon will disintegrate into rubble 21,760 miles (35,100 km) above Neptune and the "repulsive" forces will spread the debris out into the most massive and extensive ring in the solar system.

However, recent calculations reveal that the Triton breakup won't occur for another billion years.

Neil F. Comins is professor of astronomy and physics at the University of Maine and author of What If The Moon Didn't Exist? *published by HarperCollins.*

Following years of frustration and scorn, Geoff Marcy

Planet

and Paul Butler have gone on to discover more

Hunters

planets than anyone else in history. **by Sally Stephens**

Geoff Marcy, an astronomer who has discovered more extrasolar planets than anyone else, can point to the exact moment his planet search began. In the winter of 1983, he was a postdoc at the Observatories of the Carnegie Institution in Southern California. And he was not happy with his life. His research on stellar magnetic fields wasn't going well. He found himself slipping back into the insecurity he had felt as a grad student. "I remember feeling so low, I wondered, 'What am I gonna do? I'm not cut out to be an astronomer.'"

One morning, as he stood in the shower, not really wanting to go in to work that day, he came to a decision. "I have to take a hold of my life. I can't play the game of trying to do research that everybody wants me to do. I've got to do a project that is meaningful to me at a gut level." The question that most resonated within him: Is our solar system special? By the time he got out of the shower that morning, Marcy had

LEFT: Artist John Whatmough's rendition of the planet (and a hypothetical moon) orbiting 47 Ursae Majoris. INSET PHOTOS: Planet hunters Geoff Marcy (left) and Paul Butler have discovered or co-discovered six planets orbiting other stars. Courtesy San Francisco State University

decided to look for evidence of planets circling other stars.

He wasn't interested in finding just any size planet orbiting at any distance from its star, however, although that would be scientifically important. What Marcy really wanted to detect were true analogs to our own solar system: Jupiter-size giants orbiting about five astronomical units from their star.

DETECTING PLANETS

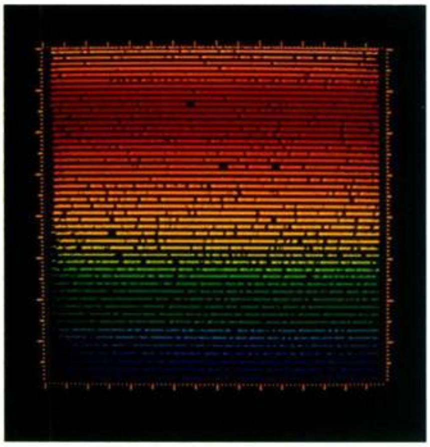
Planet detection is a game of looking for very subtle changes in a star's spectrum over time. As a planet orbits its star, its gravity causes a slight "wobble" in the star's motion. This wobble shows up as tiny shifts in the star's light as the star is sometimes pulled slightly toward Earth and sometimes pulled slightly away from Earth. This "Doppler shift" is familiar to anyone who's heard the changing pitch of a race car or ambulance's engine as it zooms past. The more massive the planet or the closer it is to the star, the larger the Doppler shift it produces. But observing this seemingly simple shift would prove maddeningly difficult to do.

As Marcy researched his new project, he realized he would need extraordinary measurement precision to find evidence of Jupiter-size planets. Indeed, the precision he needed wasn't even possible in 1983. After taking a faculty position at San Francisco State University a year later, he enlisted Paul Butler, then a physics graduate student, in his quest to find planets. Butler had a bachelor's degree in chemistry, in addition to one in physics. And it was the chemical knowledge that Marcy initially hoped to tap.

To get high-precision measurements, Marcy needed to identify a gas that would have lots of lines in the visible region of the spectrum. Every gas absorbs light at very specific wavelengths. If the gas is placed in the path of a star's light at the telescope, dark "absorption lines" will appear in the star's spectrum at those same wavelengths. These absorption lines become, in effect, a ruler for measuring the back-and-forth motions of a star that is being gently tugged by the gravity of an orbiting companion.

Two contenders quickly emerged: thiophosgene, a chemical cousin of World War I's mustard gas, and chlorine dioxide, an almost iridescent, yellow-gold gas that explodes if exposed to sunlight, even at small concentrations. "For about six months," Butler recalls with a smile, "I had a little Styrofoam beer cooler full of dry ice. On one side I had chlorine dioxide. On the other side I had thiophosgene. If OSHA had come by my little grad student office, the whole place would have been condemned." Eventually, Marcy and Butler settled on iodine gas. It's relatively nontoxic and it has plenty of lines in the visible spectrum. Now they could begin their planet search in earnest.

Marcy and Butler struggled to get precisions high enough to find other Jupiters. "For years these guys were in the dark," says University of California at Santa Cruz astronomer Steve Vogt, "flying on hope, on faith, on the total conviction that if they just kept pounding away at their work, eventually it would bear fruit."



A star's spectrum is cluttered with hundreds of dark lines, each of which results from atoms in the outer atmosphere absorbing light at specific wavelengths. To find planets, Marcy and Butler look for minuscule back-and-forth movements in these lines as the star is being tugged by an orbiting companion. Geoff Marcy and Paul Butler

Marcy and Butler knew that Jupiter causes a wobble in the sun's motion of 12.5 meters per second (28 miles per hour). To detect this slow speed in another star, they had to reduce the uncertainty of their Doppler measurements to three meters per second (the speed of a brisk walk) to ensure that the wobble speed rose above the noise of the measurement.

No one had ever achieved such precision. "Going down to three meters per second was 50 to 100 times better than what most people had done," says Vogt. Through much hard work and exhaustive computer programming, their precision gradually improved. Then, around 1987, they found themselves unable to get any better than 50 meters per second. They began to fear they'd never find Jupiters. "It was just awful," Marcy remembers. "We were totally distraught."

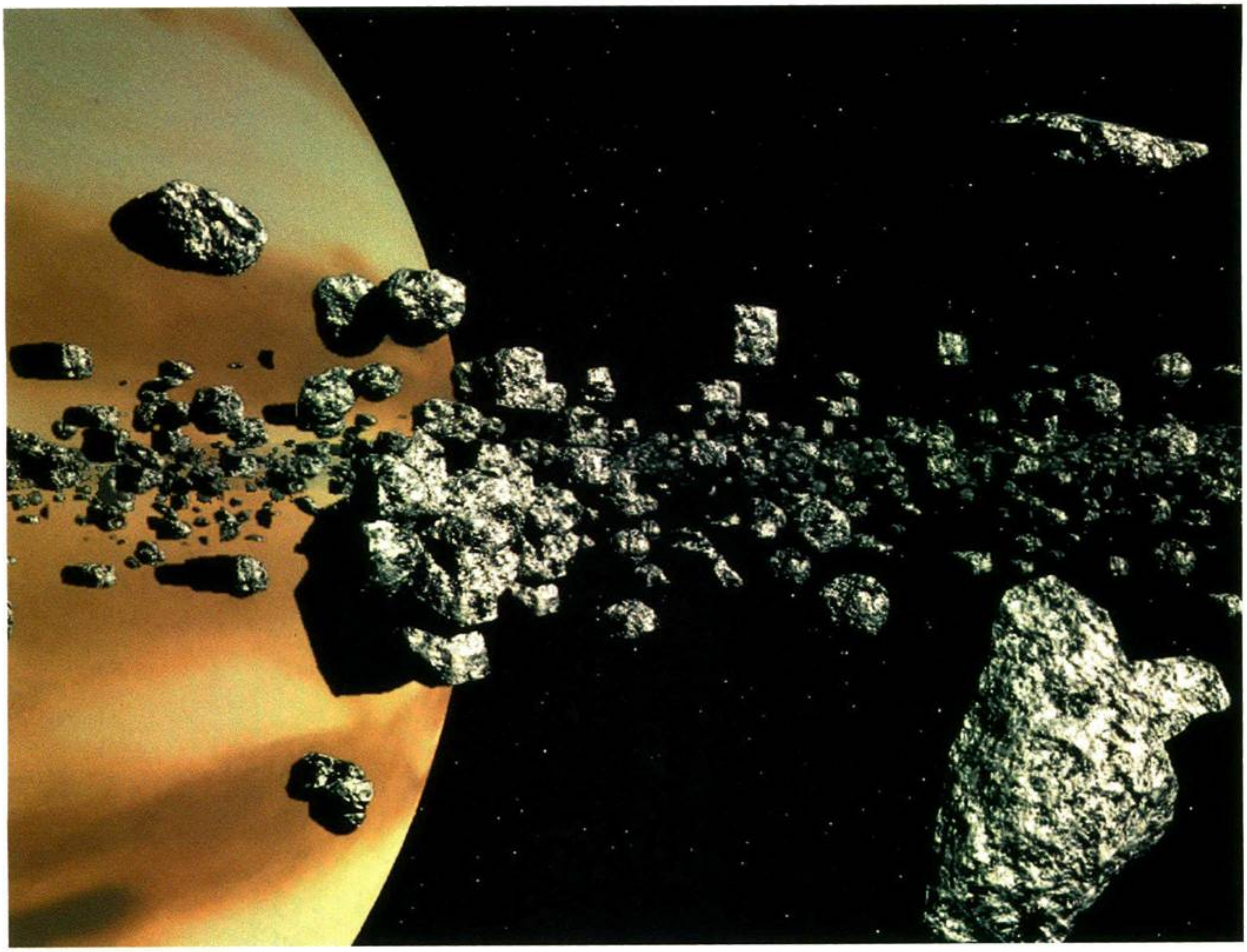
THE PERILS OF POINT SPREADS

They had stumbled upon a fundamental limitation of spectrometers, the instrument they used to get Doppler shifts. "What any spectrometer does is slightly smear the image," Butler points out. In an ideal world, light passing through the instrument would illuminate the detector in a perfect circle. But, in reality, there's always some distortion to the circle. The shape of this distortion or smearing is known as the point-spread function, or PSF. And it was killing them. "It turns out very small, one-percent deviations [from a perfect circle] will cause 25-meter-per-second errors," Butler explains.

The PSF problem affects all astronomers, but no one else had ever really needed to worry about it. "Most people just lived with it," Marcy says. "People don't care about precision at the level we're doing things," Butler argues, "because it's just too hard."

"It took us a year or two just to figure out what the problem was," Marcy recalls. "And then another year or two to figure out that we had to do something about it." They realized they could remove the effects of PSF smearing with the computer program they used to process each spectrum. The resulting program took six computer hours per spectrum to run. When Butler mentioned this processing time at an astronomy conference in the summer of 1992, he was laughed off the stage. With hundreds of spectra to study, six hours seemed an absurdly long time to most of the astronomers present. "You haven't analyzed [all] your data by the time you have to go back to the telescope," Marcy says, explaining the laughter. "You're losing ground all the time."

"We were stuck between a rock and a hard place," he continues. "If we don't include the PSF, our velocities are no better than plus or minus 50 meters per second. If we do include the PSF, people think we've gone way overboard, and maybe impractically so." Ultimately, Marcy and Butler persisted. After all, both were driven to find planets truly like Jupiter, and that



John Whatmough

meant they had to have three meters per second precision. "We didn't have any choice," Marcy adds.

By this time, many astronomers would have given up and looked for another project. But for Marcy and Butler that was never an option. "Failure is bad, and sticking to it is good," is how Marcy jokingly describes what drives him. "Fortunately, Paul feels the same way. When Paul wants to do something," Marcy explains, "he puts his blinders on and he doesn't look at anything else, in his professional life, in his personal life. . . The two of us are closely matched in that."

Final completion of the computer code in late 1994, about eight years after they began their planet search in earnest, coincided with an improvement to the spectrometer that lessened the amount of smearing. "Those two things combined," Marcy notes, "and immediately our errors went down to 10 meters per second. And within a few months, a little more tweaking, boom, it was down to three meters per second."

SCOOPED!

On October 6, 1995, two Swiss astronomers, Michel Mayor and Didier Queloz, stunned the world with the announcement that they had detected a planet around the star 51 Pegasi. "First, I was pretty sure they were wrong," Marcy remembers. Colleagues had nicknamed him "Dr. Death," because he had proven so many previous planet claims to be in error. "Then I thought, 'if they're right, we've been scooped. Major bummer.' But my third reaction was that this is fantastic. This is the discovery that humanity has waited for for more than 2,000 years, since the time of the Greeks when Epicurus and Aristotle argued about whether or not the universe might have other Earths."

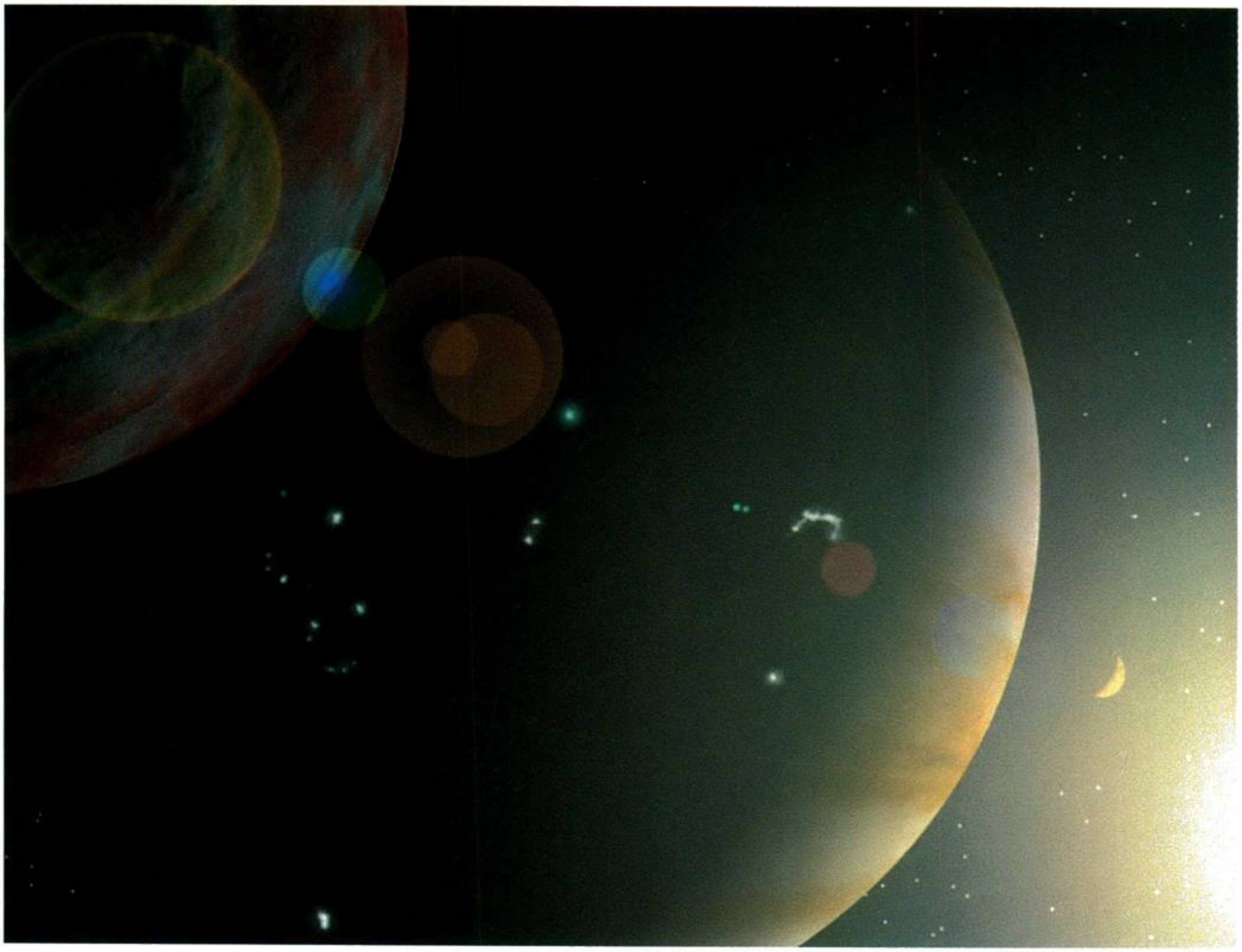
Marcy and Butler just happened to have telescope time at Lick Observatory four days after the Swiss team's announcement. Within days they confirmed the Swiss discovery. "I remember driving off the mountain with Paul," he adds. "We were just sort of in stunned silence. They were right."

Do the giant planets discovered by Marcy and Butler have rings, as depicted here? All the gas giants in our solar system have rings.

But the planet around 51 Peg, at least half the mass of Jupiter, orbited closer to its star than Mercury does the sun. Marcy and Butler had been looking for planets that took years to circle their stars, not mere days like 51 Peg. The discovery inspired both astronomers to go back through their observations and look for similar short-period planets. "The door swung wide open," Marcy recalls. More planetary detections quickly followed. So far, Marcy and Butler have found six planets orbiting sun-like stars, more than twice as many planets as all other researchers have found combined.

CONSUMED BY THE MEDIA

When you meet them, both astronomers come across as relatively quiet and unassuming. Marcy is the shorter of the two. He dresses like the faculty member he is, favoring work



John Whatmough

shirts and corduroys or Dockers. Butler, a post-doc, often comes to work in tie-dyed T-shirts and shorts. The two share a narrow, cramped office at the University of California at Berkeley, although Marcy continues to teach at San Francisco State. Their desks sit side by side along one wall, identical computers on each.

On Butler's desk, amid the stacks of papers and printouts, is a book about baseball legend Jackie Robinson, a gift from Marcy. Both men grew up in Southern California and call themselves Dodger fans. Posters of musicians Sarah Vaughan, Charlie Parker, and John Coltrane decorate one corner of the room, a testament to Butler's love of jazz. A typical day finds both Marcy and Butler at their office until well after midnight. "The neat thing about working late," Marcy explains, "is that after 7 p.m. it's really quiet. You can focus in and the phone doesn't ring."

That became especially important once their confirmation of the 51 Peg planet was announced. "Within two days, we got calls from every newspaper, magazine, and TV station that there was," Marcy recalls. "For the next three to six months, every single day was like that, just endless phone calls, endless e-mails, endless requests."

After announcing their first two planets in January 1996, they appeared on "Nightline," were named "Persons of the Week" by ABC Evening News, and were featured in a *Time* magazine cover story. "My life was really consumed by this," Marcy laments. "I haven't picked up my cello in two years. I've had to say to a lot of my friends, 'I'm really sorry. I just don't have time.'" He's married to Susan Kegley, a former chemistry lecturer at the University of California at Berkeley. "One day we were in the grocery store, in the aisle with the fruit drinks, and Susan said, 'I am sick of hearing about those planets.'"

The celebrity may have interfered with their personal lives and kept them from working on their research as much as they wanted, but it also opened new doors. "We're getting more telescope time and we're getting funds we never got before," admits Marcy. And they've just been given, free of charge, two state-of-the-art computers that allow them to process a spectrum in 20 minutes, not six hours. "Sun Microsystems is excited about the planets too," he laughs.

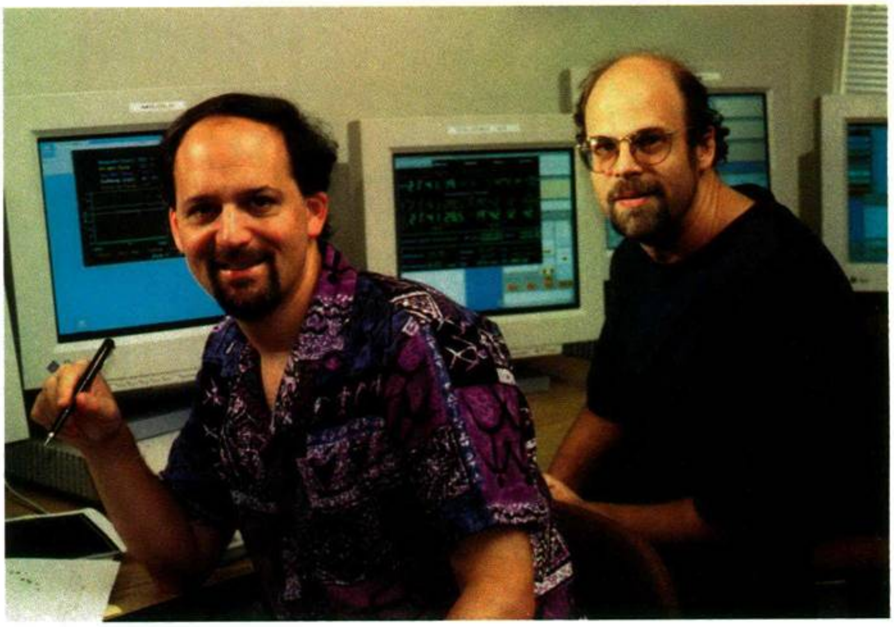
Surprisingly, most of the planets discovered so far, like the one pictured above, are giants that orbit extremely close to their host stars.

WORKING THROUGH THE BACKLOG

Ironically, Marcy and Butler's obsession with getting such high precision may have helped Mayor and Queloz be the first to find a planet circling a sunlike star. Marcy and Butler had spent so much time getting their computer programs up and running that they had no time left to analyze the spectra they'd been accumulating all along. Buried within that backlog of data was solid evidence of planets, but Marcy and Butler hadn't had a chance to look for it. "We sacrificed the first detection of extrasolar planets in favor of developing the very best Doppler technique," Marcy concedes.

In one final irony, nearly all of the planets detected so far produce wobbles in their stars' motion much larger than the 12.5-meters-per-second motion caused by Jupiter. Marcy and Butler hadn't needed extraordinarily high precision to find these planets after all because — contrary to the prevailing theories of the time — they orbit extremely close to their parent stars. Marcy and Butler have since gone through their backlog and "picked the plums." "Those are the easiest objects to detect," says Butler. "Because they're in close, you get the biggest possible wobble and you get many, many orbits in a few months." So Mayor and Queloz's observations, even though not as accurate as Marcy and Butler's, turned out to be precise enough to detect the 51 Pegasi planet (which produces a tug of 53 meters per second).

But none of this really bothers Marcy and Butler. Their motivation has always been to find true analogs to our own solar system: Jupiter-size planets in Jupiter-size orbits.



Geoff Marcy and Paul Butler

Geoff Marcy and Paul Butler conduct their planet search from the remote operations room of the giant 10-meter Keck I Telescope.

AIMING FOR TRUE JUPITERS

More research groups have now joined the hunt for planets. Marcy and Butler think each group needs to find its own niche. The groups with accuracies around 10 meters per second will continue to detect large planets close by their stars, like those already found. "They'll continue to find 51 Pegs," Butler says. "But we want Jupiters." At the moment, Marcy and Butler appear to be the only team with enough precision to find true Jupiters. "Paul and I have a few Jupiter candidates that look pretty good that we haven't announced," Marcy confesses. But they've only had high accuracies for three years, and they need another few years worth of data to confirm if the suspected Jupiters — with their long orbital periods — are really there.

"What we would like to do is push our precision down to one meter per second," Butler explains, "get down to where we can make Saturn, maybe even sub-Saturn detections." Unfortunately the stellar wobble induced by an Earth-size planet is too small for Marcy and Butler to detect. But, as Butler points out, "If we see a Jupiter at five AU, that's screaming that this is a system that's like the solar system. And you'd be willing to bet a couple of bucks at that point that maybe there'd be some Earth-like rocks closer in."

In September 1997, Marcy and Butler parted company, at least physically, when Butler headed off to Australia for a few years to extend the planet search to Southern Hemisphere stars with the 3.9-meter Anglo-Australian Telescope (AAT). The two will continue to work closely together, however. "Australia and Berkeley are less than a millisecond away by Internet," jokes Marcy. "So it won't matter whether he's Down Under or Right Over."

Combining observations at the AAT, Lick, and Keck Observatories, Marcy and Butler plan to monitor all 500 of the nearest, brightest, sun-like stars. "What we want to do is sort of humanity's first reconnaissance of the solar neighborhood for planets," Marcy says. He hasn't forgotten his epiphany in the shower 15 years ago. "One way or another, within three to six years, we're going to know whether or not our solar system is special." ▣

MARCY AND BUTLER'S SIX PLANETS

Star	Minimum Planet Mass (Jupiter = 1)	Average Distance from Star (AU)	Orbital Period
Tau Bootis	3.64	0.04	3.3 days
Upsilon Andromedae	0.63	0.05	4.6 days
55 Rho^1 Cancri	0.85	0.12	14.7 days
70 Virginis	6.84	0.47	116.7 days
*16 Cygni B	1.74	1.70	2.2 years
47 Ursae Majoris	2.42	2.08	3.0 years

*Co-discovered by William Cochran and Artie Hatzes, University of Texas at Austin

Marcy and Butler's web site: http://www.physics.sfsu.edu/~gmarcy/planetsearch/planetsearch.html

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Freelance science writer Sally Stephens is the former editor of Mercury *magazine. Her last article for* Astronomy *was "The Biggest, The Brightest, the Best" in the June 1997 issue.*

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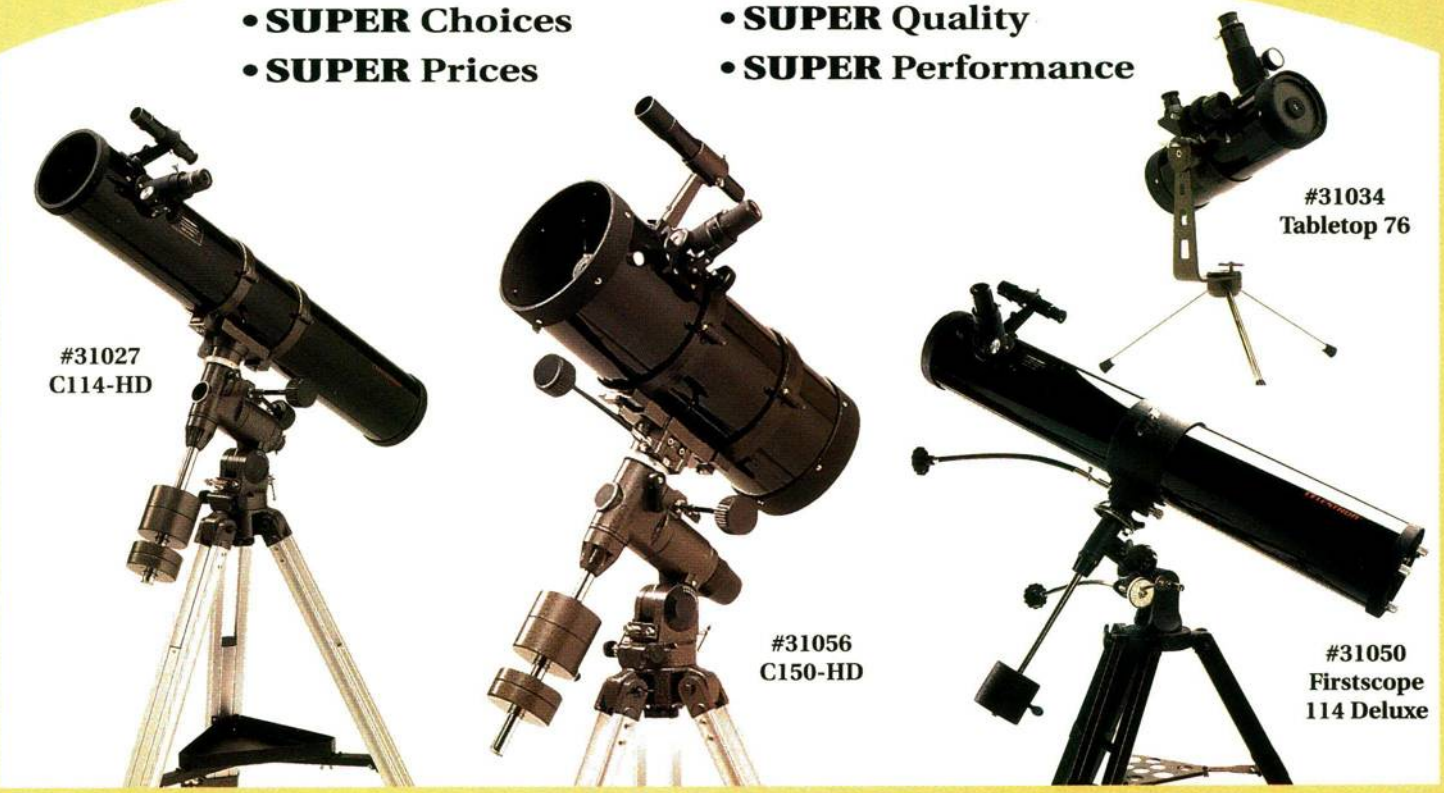

- Sturdy Equatorial and Altazimuth Mounts
- Size Ranges from 76mm (3") through 150mm (6")

With 9 models to choose from there is sure to be one that matches your requirements.

The 76mm (3") aperture of the Firstscope 76 models offer much of the performance of the Newtonian reflector design in a compact, highly portable instrument. They are perfect for the beginning observer and for casual gift-giving.

Celestron offers three different Firstscope 76's: the standard altazimuth mount (AZ), the Tabletop 76 altazimuth and the equatorial mount (EQ).

The superb optics of these telescopes offer dazzling images of the moon; Saturn and its rings; Jupiter, with its belts and moons; and hundreds of deep-sky objects, including brighter galaxies, nebulae and star clusters.

The 114mm (4.5") Newtonian equatorial telescope is the most popular size telescope for the more serious beginning or intermediate level astronomy enthusiast, and for good reason. The large light gathering power of this 4½" telescope makes it ideal for deep-sky observation of galaxies, star clusters and nebulae, as well as lunar and planetary observing. This makes for a very useful and versatile instrument that can take an observer from the very first time looking through a telescope's eyepiece, through years of observing interesting subjects near and far in the night sky.

Celestron offers five different 114mm Newtonian equatorial telescopes, making it a sure bet that one of them will have just the combination of features and performance you're looking for.

The Firstscope 114 series has four models. Each is a high quality, economical telescope with a superb optical system housed in a glossy black metal tube. The equatorial mount is quite stable, with setting circles and slow motion controls on both axes for easy, smooth tracking. Strict adherence to Celestron's tough quality standards for manufacturing, assembly and testing ensures that each telescope performs well.

The C114-HD attaches to the CG-4 mount, a very rigid German equatorial mount designed for the discriminating buyer. This heavy duty 114mm Newtonian stands out from the other 114mm telescopes on the market by having by far the best mount.

The C150-HD is a 6" Newtonian telescope which uses the CG-4 mount. This telescope was engineered for the more serious astronomer who wants not only a very rigid mount but also a larger aperture. The premium optics of this heavy duty telescope are manufactured to Celestron's uncompromising standards. The star images are classic textbook airy disks.

The C150-HD offers views of intriguing lunar details and high power planetary viewing. You can see detail in Jupiter's equatorial belts, the beautiful ring structure of Saturn and the polar caps of Mars. This telescopes is large enough to observe hundreds of deep-sky objects with ease, fully resolve many globular star clusters, and allow you to enjoy viewing brighter nebulae, double stars and galaxies.

CELESTRON®

For full details on the complete line of Celestron Newtonians and the wide assortment of accessories available contact a Celestron dealer, Celestron or visit our web site.
WEB site at http://www.celestron.com

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LARGE APERTURE

CELESTRON

ULTRA PORTABILITY

C5+ shown with
optional hand control

C5+

- For astronomy on the go, the C5+ can't be beat. Due to its excellent Schmidt-Cassegrain design and careful crafting, this telescope is a serious, high performance instrument, and its compact size makes it totally portable.
- The optical system of the C5+ features Starbright® coatings. An *Astronomy* magazine review said, "the C5 I tested contained superb optics. At high powers, stars exhibited a clearly defined Airy disk surrounded by a bright first diffraction ring and several successively fainter outer rings. This was a telescope that demonstrated how well Schmidt-Cassegrain optics can perform and met Celestron's promise of diffraction limited optics."
- The C5+ features Celestron's legendary hand-figured, diffraction limited optical system for optical performance you can depend on. The reputation for excellence of this telescope is such that it was chosen by NASA, over all other competitive models, for several space shuttle missions.
- The DC electronics of the C5+ have a built-in drive controller, powered by a 9 volt alkaline battery. A comment from the *Sky & Telescope* review — "the digital electronics delivered a near perfect sidereal tracking rate."
- Standard equatorial wedge supplied with the C5+ has a built-in bubble level and is adjustable from 0° to 90°.

STANDARD SPECIFICATIONS:

- 5" (127mm) Aperture
- Focal Length of 1250mm
- Focal Ratio of f/10
- Standard 1¹/₄" Accessories Include: 25mm SMA Eyepiece (50x), Star Diagonal, and Visual Back
- 6x30 Finderscope
- Unique Single-Arm Fork Mount with Carrying Handle
- Weight: 23 lbs. (including the wedge)
- Made in the U.S.A.
- The C5+ can even be converted to a computerized telescope with optional accessories.

ULTIMA® 9¼ and ULTIMA® 11

- The compact Schmidt-Cassegrain design makes these powerful telescopes portable enough to load in your car and take out to your favorite observing sites. Further, this design is user-friendly, so even a beginner can enjoy using a large telescope.
- The images captured by these versatile telescopes are superb, due to optics designed to perform flawlessly.
- 9¹/₄" (235mm) Aperture, 11" (279mm) Aperture
- 9¼" Focal Length of 2350mm, 11" Focal Length of 2800mm
- Focal Ratio of f/10
- Starbright® Coatings
- 6x30 Finderscope – 9¼", 7x50–11"
- Hand Controller
- Focusing Micrometer on 9¼"
- PEC Electronics
- Ergonomic, user-friendly operation is the trademark of the Ultima® telescopes. The Ultima 9¹/₄ and 11 telescopes were designed with functional use as a top priority, and they deliver.
- Standard 1¹/₄" Accessories Include: 25mm SMA Eyepiece (94x) and Star Diagonal, 26mm Plössl (108x) for 11"
- Adjustable, Rigid Metal Tripod, Heavy Duty Wedge and Deluxe Latitude Adjuster.
- Weight: 74 lbs. for 9¼", 80 lbs for 11"
- Made in the U.S.A.
- The superb optics use high transmission Starbright® coatings to capture the brightest, sharpest images.
- The newly designed fork tines of the mount and drive base are sand cast and they add greater stability.
- The totally cordless DC servo quartz drive system runs on an ordinary 9 volt battery.
- Celestron's optional Advanced Astro Master® can be added to create a computerized telescope.

ULTIMA® 11 **ULTIMA® 9¼**

CELESTRON® *For more detailed information on these telescopes, contact a Celestron dealer or Celestron.*
Visit our Web site at http://www.celestron.com

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CELESTAR 8 TELESCOPES

Lowest Prices Ever!

CELESTRON
CELESTRON

CELESTAR 8

- An economical but full featured 8" Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8 to offer the **lowest price ever** on a Celestron fork mounted 8" with so many features.
- No sacrifice was made in the optics. The unsurpassed superior quality Celestron hand-figured system delivers diffraction-limited optics. Starbright® coatings are standard.
- The electronics are DC for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the *Sky & Telescope* review — "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 is powered by a 9 volt alkaline battery.
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90°.
- The new and unique Wedgpod is a combination tripod and wedge. It has a fixed height (33") and is lightweight without compromising its stability.
- Made in the U.S.A.
- Standard accessories included: 6x30 Finderscope, Star Diagonal – 1-1/4" and a 25mm SMA Eyepiece – 1-1/4" (81x).

CELESTAR 8 DELUXE

- This telescope utilizes the same superior optics used in all of Celestron's 8" Schmidt-Cassegrain telescopes and has all of the features of the Celestar 8, but is enhanced, for those who prefer a premium version of the spectacular Celestar 8.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging.
- The standard accessories for this telescope include: a Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod that's exceptionally rigid and sturdy, with adjustable height.
- Also standard is a large 9x50 Finderscope, and a multi-coated 26mm Plössl Eyepiece – 1-1/4" (78X).

CELESTRON
Advanced Astro Master

ADVANCED ASTRO MASTER®

The Celestar 8 Computerized and the Celestar 8 Deluxe Computerized telescopes are the same as the Celestar 8 and Celestar 8 Deluxe but with the addition of a factory **installed** and **tested** Advanced Astro Master®.

The pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9 volt battery.

Contains an RS-232 serial interface to enable usage with PC programs like "The Sky"™ by Software Bisque.

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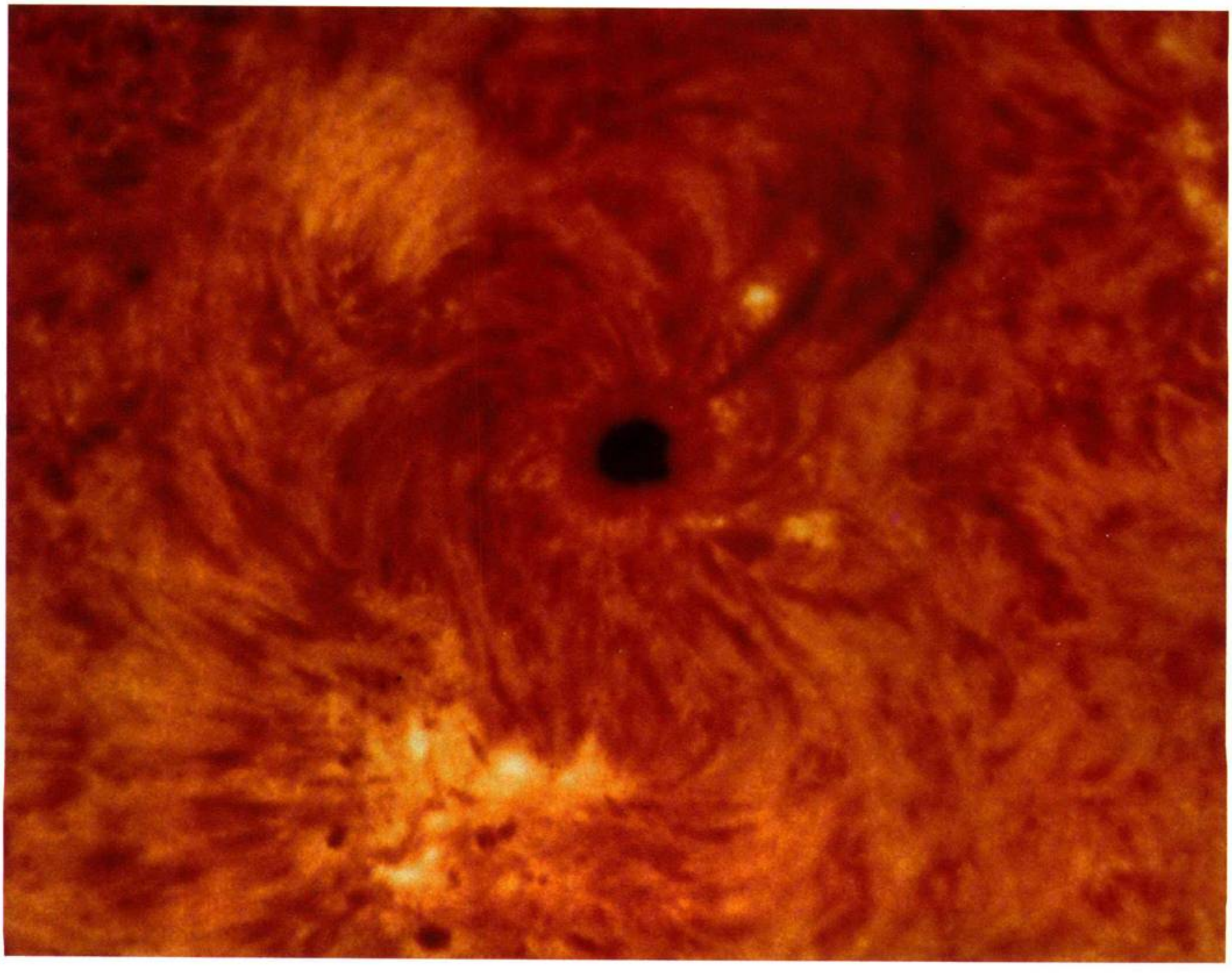
THE SKY SHOW

The long days of summer mean it's time to try your hand at some daytime observing. This month, try Venus and Saturn, and don't forget the sun. by Martin Ratcliffe and Alister Ling

▶ Though often forgotten by stargazers, the sun is a worthwhile object to scrutinize. For one thing, it's easy to spot. It's also relatively close to Earth, a mere 93 million miles, giving it a fairly large visual diameter (0.5°). The sun is the only star whose surface amateur astronomers can study. So if you like to sleep at night, the sun may be perfect for you. Another reason to dust off those solar filters: We're approaching solar maximum. This year has already brought an increase in sunspot numbers.

Sunspots are one of the easiest solar features to observe, and small telescopes are ideal — especially when used to project the sun's image onto a smooth surface. Over a few days or weeks, some sunspots may become highly complex, lasting more than a solar rotation (27 days). Others appear out of nowhere, grow a little, then disappear. Sunspots have a deep black center (the umbra) with a lighter peripheral region (the penumbra). Sometimes these can be circular, at other times they are quite complex with features that change shape daily. Though these dark regions appear black to us, in reality they are not black at all. Their temperature is slightly cooler — by 1000 Kelvins — than the rest of the sun's surface. This makes them appear darker than the glowing hot 5800 K of their surroundings.

If you use the correct viewing method, daily drawings of the sun can be recorded easily. Never look at the sun directly through



A classic sunspot, with its dark, nearly circular umbra and the lighter surrounding penumbra, reveals the dynamics of the sun's surface or photosphere. Solar filaments are also seen as they appear to swirl and radiate out from the penumbra.

Donald F. Trombino and Jeff Pettit

JULY 1998

1 First quarter moon is at 2:43 p.m. EDT

2 The moon is at apogee (251,171 miles from Earth), 1:30 p.m. EDT

3 Venus passes 4° north of Aldebaran, 1 a.m. EDT
Earth is at aphelion (94.5 million miles from the sun), 8 p.m. EDT

9 Full moon is at 12:01 p.m. EDT

10 Asteroid Iris is at opposition, 7 p.m. EDT

11 The moon passes 3° north of Uranus, 9 a.m. EDT

16 The moon is at perigee (229,721 miles from Earth), 9:52 a.m. EDT
Last quarter moon is at 11:13 a.m. EDT
Mercury is at greatest eastern elongation (27°), 11 p.m. EDT (page 74)

17 The moon passes 2° south of Saturn, 1 a.m. EDT

19 The moon passes 0.3° north of Aldebaran, 5 p.m. EDT

21 The moon passes 4° south of Venus, 8 a.m. EDT
Asteroid Ariadne is at opposition, 10 a.m. EDT
The moon passes 5° south of Mars, 11 p.m. EDT

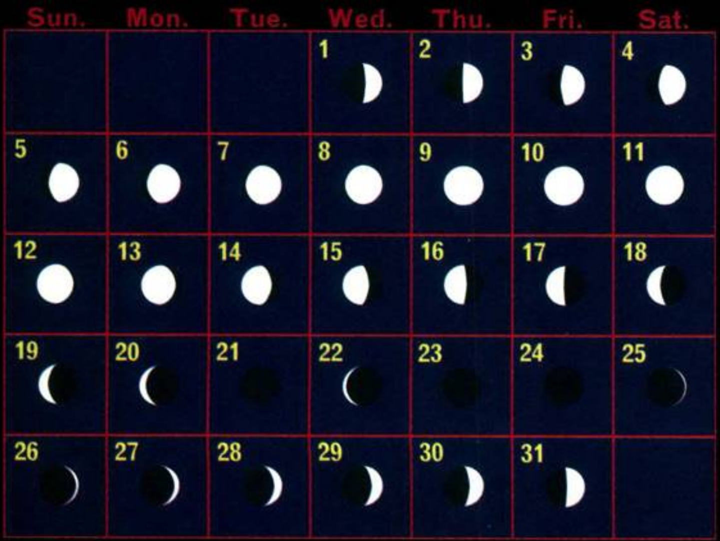
23 New moon is at 9:44 a.m. EDT
Neptune is at opposition, 4 p.m. EDT (page 73)

25 The moon passes 2° north of Mercury, 10 a.m. EDT
The moon passes 0.7° south of Regulus, 5 p.m. EDT

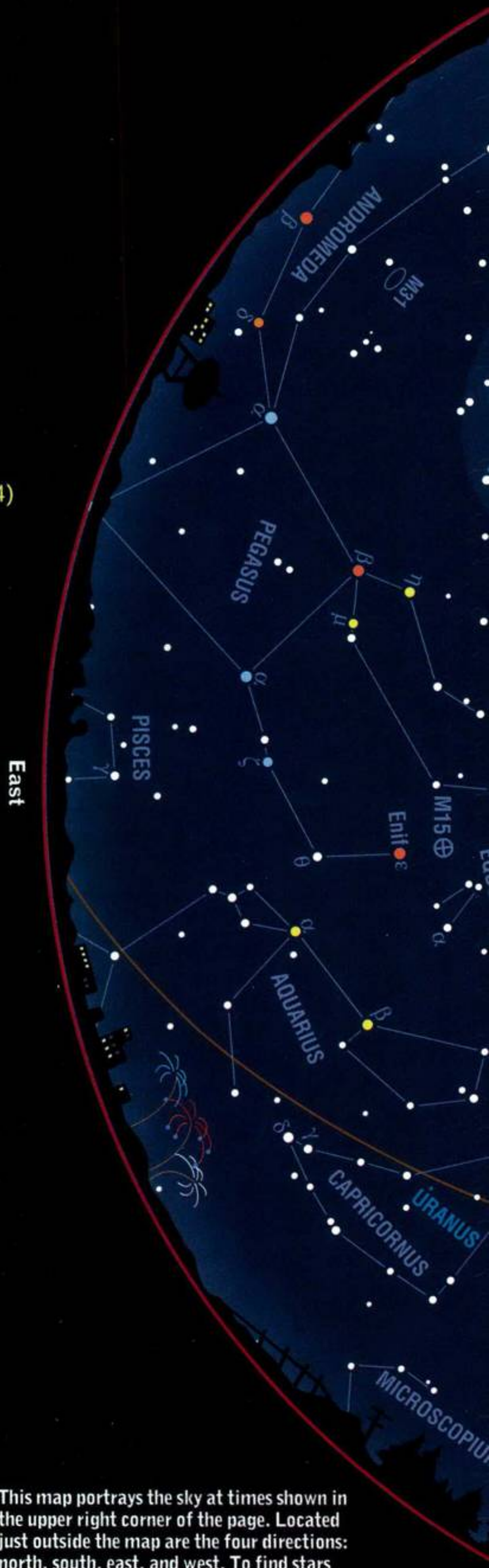
28 Southern Delta Aquarid meteor shower peaks

30 The moon is at apogee (251,221 miles from Earth), 8:09 a.m. EDT

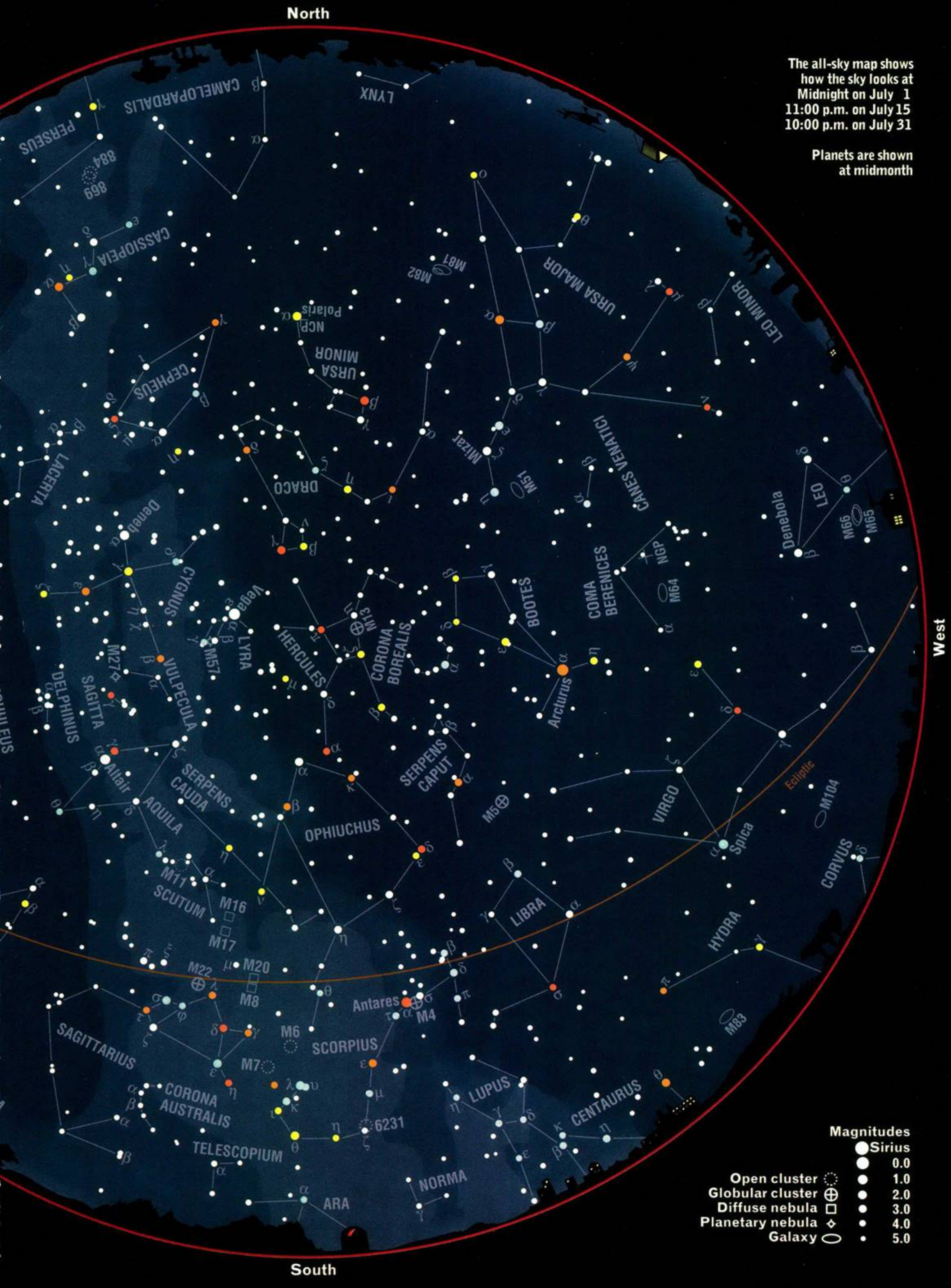
31 First quarter moon is at 8:05 a.m. EDT
Asteroid Amphitrite is at opposition, 11 a.m. EDT



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	



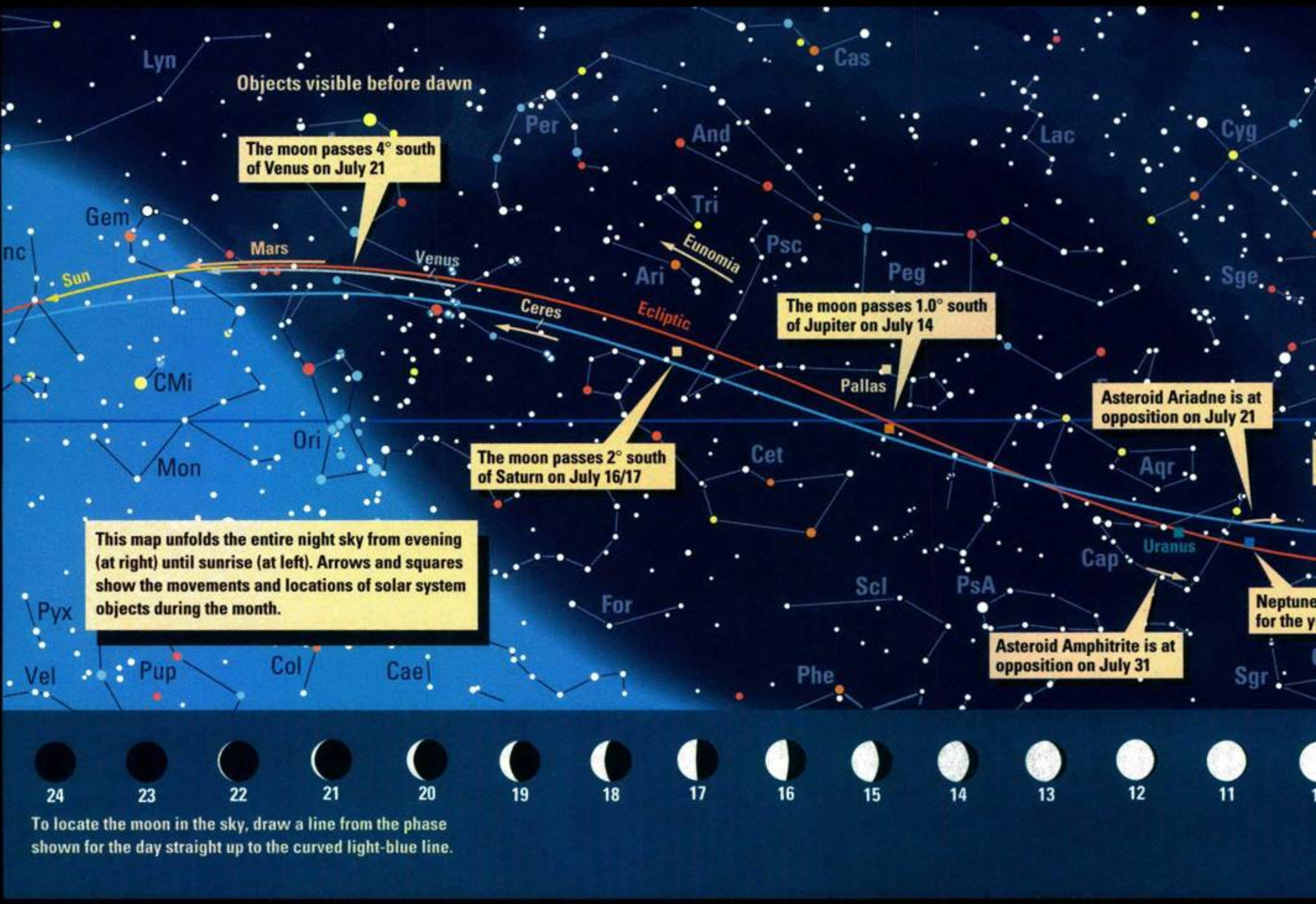
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
West
South
PERSEUS
CAMELOPARDALIS
LYNX
869
884
CASSIOPEIA
URSA MAJOR
M81
M82
LEO MINOR
Polaris
NCP
URSA MINOR
CEPHEUS
LACERTA
DRACO
Mizar
CANES VENATICI
M51
LEO
Denebola
M66
M65
Deneb
CYGNUS
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
BOOTES
COMA BERENICES
NGP
M64
Arcturus
M27
VULPECULA
SAGITTA
DELPHINUS
Altair
AQUILA
SERPENS CAUDA
OPHIUCHUS
SERPENS CAPUT
M5
VIRGO
Ecliptic
M104
Spica
CORVUS
M11
SCUTUM
M16
M17
LIBRA
HYDRA
M22
M20
M8
Antares
M4
M6
SCORPIUS
SAGITTARIUS
M7
M83
CORONA AUSTRALIS
LUPUS
CENTAURUS
6231
TELESCOPIUM
NORMA
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
Midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31

Planets are shown
at midmonth

THE PATH OF THE PLANETS


Lyn
Objects visible before dawn
Per
Cas
And
Lac
Cyg
Gem
nc
Sun
Mars
Venus
Tri
Eunomia
Ari
Psc
Peg
Sge
Ceres
Ecliptic
CMi
Pallas
Ori
Mon
Cet
Aqr
Uranus
Cap
Scl
PsA
For
Pyx
Vel
Pup
Col
Cae
Phe
Sgr
24
23
22
21
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19
18
17
16
15
14
13
12
11

The moon passes 4° south of Venus on July 21

The moon passes 1.0° south of Jupiter on July 14

The moon passes 2° south of Saturn on July 16/17

Asteroid Ariadne is at opposition on July 21

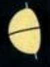
Asteroid Amphitrite is at opposition on July 31

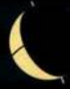
Neptune for the y

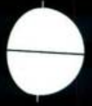
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

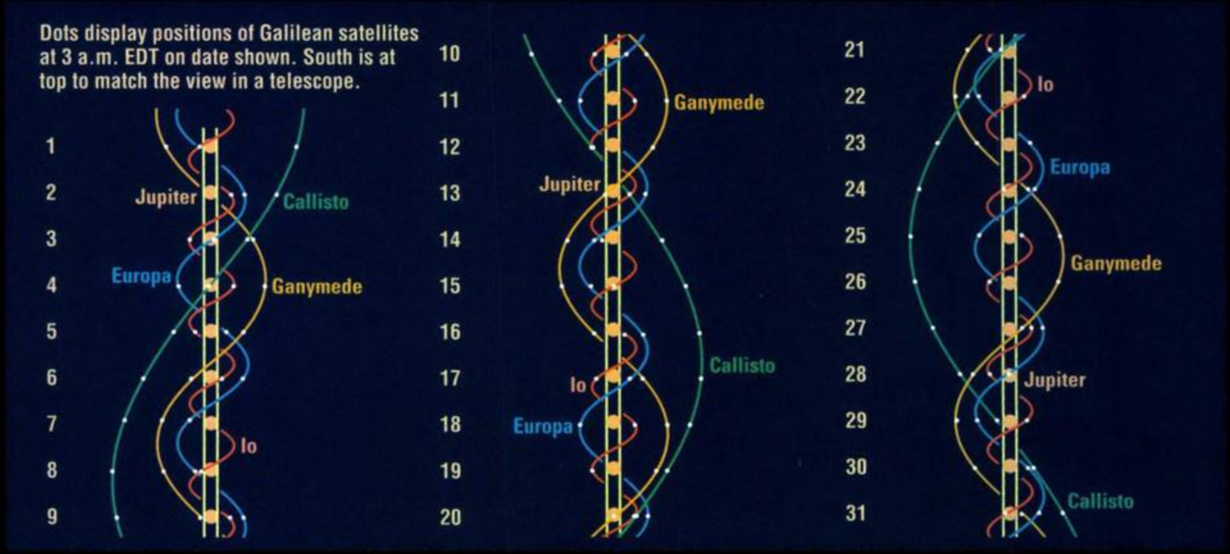
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	July 1	July 31	July 15	July 15	July 15
Magnitude	–0.3	1.6	–3.9	1.6	–2.6
Angular Size	6.1"	10.1"	11.6"	3.7"	44.1"
Illumination	70%	19%	88%	99%	99%
Distance (AU) from Earth	1.105	0.666	1.443	2.505	4.473
Distance (AU) from Sun	0.398	0.460	0.723	1.558	4.978
Right Ascension (2000.0)	8h10.4m	9h56.7m	5h36.0m	6h25.6m	23h55.0m
Declination (2000.0)	21°46'	8°40'	22°23'	23°59'	–2°00'



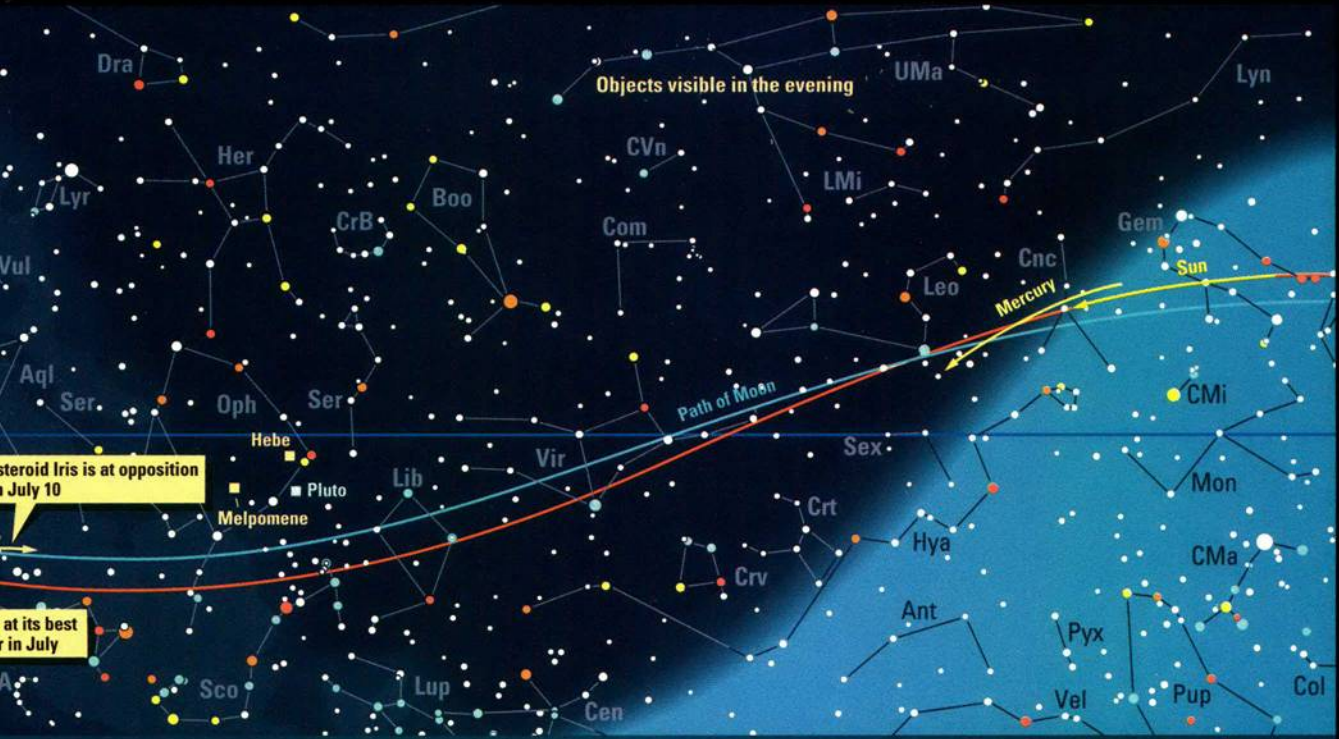




JUPITER'S MOONS

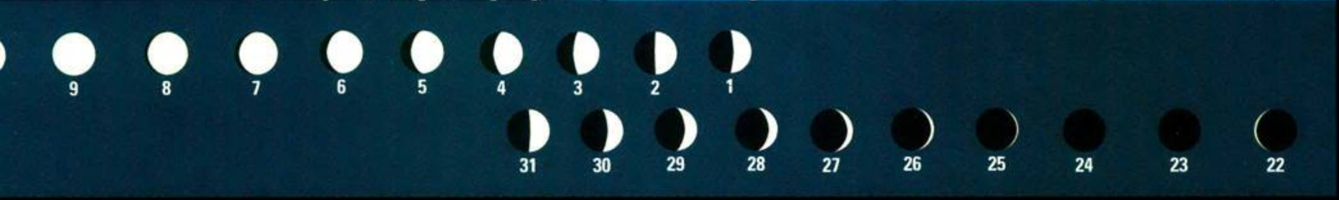


Dots display positions of Galilean satellites at 3 a.m. EDT on date shown. South is at top to match the view in a telescope.

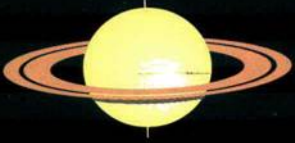

Dra
Objects visible in the evening
UMa
Lyn
Her
CVn
Lyr
Boo
LMi
CrB
Com
Gem
Vul
Cnc
Leo
Sun
Mercury
Aql
Ser
Oph
Ser
Path of Moon
CMi
Hebe
Sex
Pluto
Vir
Lib
Mon
Melpomene
Crt
Hya
CMa
Crv
Ant
Pyx
Sco
Lup
Vel
Pup
Col
Cen

steroid Iris is at opposition
n July 10

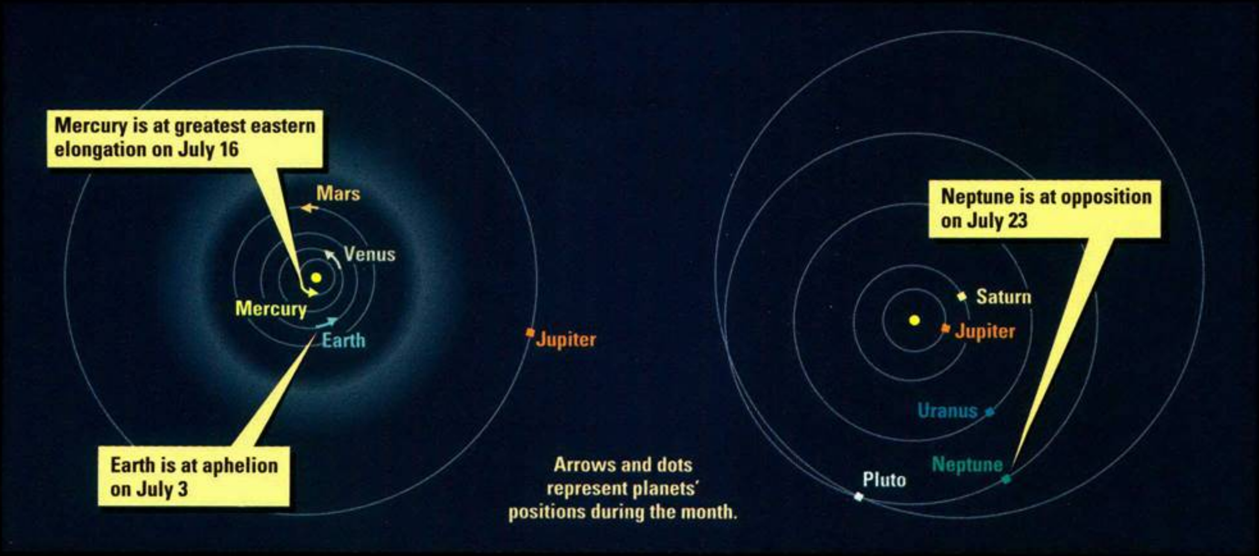
at its best
r in July


9
8
7
6
5
4
3
2
1
31
30
29
28
27
26
25
24
23
22

SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15
0.3	5.7	7.8	13.7
17.6"	3.7"	2.3"	0.1"
100%	100%	100%	100%
9.444	18.904	29.134	29.387
9.314	19.867	30.139	30.077
2h05.7m	20h56.8m	20h12.7m	16h23.4m
10°08'	–17°58'	–19°35'	–9°11'



THE PLANETS IN THEIR ORBITS


Mars
Venus
Mercury
Earth
Jupiter
Saturn
Jupiter
Uranus
Neptune
Pluto

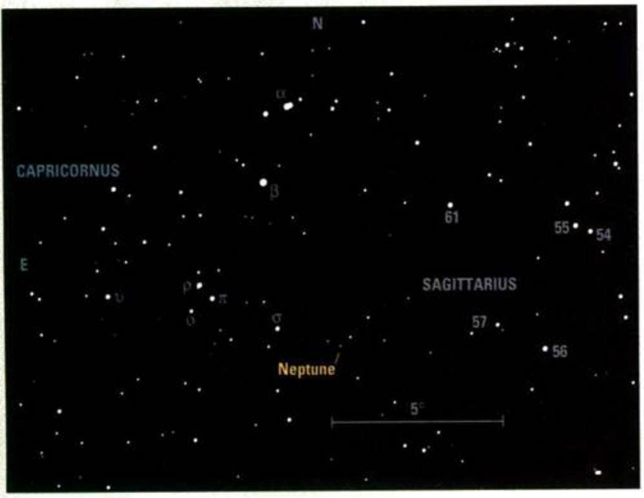
Mercury is at greatest eastern elongation on July 16

Earth is at aphelion on July 3

Neptune is at opposition on July 23

Arrows and dots represent planets' positions during the month.

First Views: Neptune at Opposition

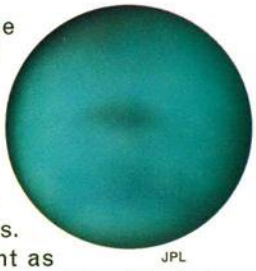


All illustrations by *Astronomy*: Elisabeth Rowan

Opposition occurs when a solar system object is opposite the sun from our vantage point on Earth. This means the object is opposite the sun in our sky, so it rises as the sun sets and sets as the sun rises. The object is visible all night. That's why opposition is important to astronomers.

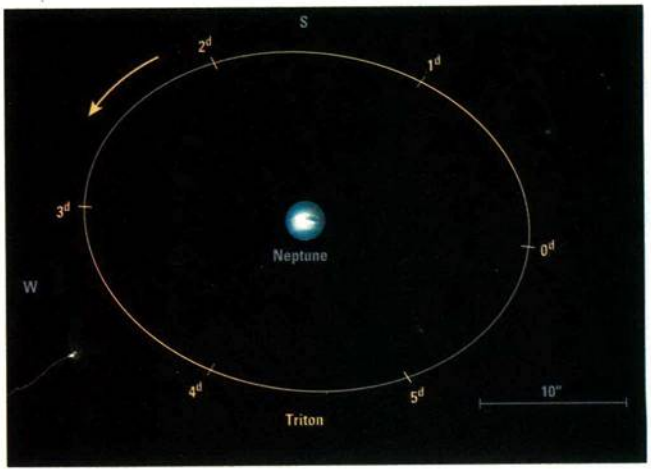
This month, Neptune is at opposition and an easy binocular target — when you know where to look. Start at the beautiful pair Alpha^1 (α^1) and Alpha^2 (α^2) Capricorni, then slide southeast some 6° (a binocular field of view) to a trio of 6th-magnitude stars. One half a binocular field of view to the west lies Sigma (σ) Capricorni. Continue west by that same amount and you should see a pair of 7th- and 8th-magnitude stars. Neptune is the fainter one.

In a telescope, Neptune presents a tiny 2.3" disk. Stare straight at it to see if Neptune stimulates your eye's color receptors, then raise the magnification as much as possible, to a maximum of 50x per inch of aperture.



JPL

If you're feeling up to it, try Neptune's largest moon, Triton. This icy world presents a considerable challenge for 8-inch scopes. At magnitude 13.5, it's as bright as Pluto. Neptune itself hinders the view with a bit of glare. To aid your quest, Triton's position is charted below. The moon's point of greatest eastern elongation is day 0 and each day in its 5d21h period is marked. Triton reaches eastern elongation on July 5 at 7:06 p.m., July 11 at 4:12 p.m., July 17 at 1:18 p.m., July 23 at 10:30 a.m., and July 29 at 7:36 a.m. (all EDT). From this point, you can calculate where Triton is on the day you are observing.



any optical instrument — it can result in permanent blindness. Your eye is a delicate instrument and looking at the sun through a telescope puts it in harm's way. Instead, roughly point your telescope at the sun and hold a large white card about a foot or so behind the eyepiece. Move the scope until the shadow of the tube is at its smallest. As you move the telescope, the image of the sun will flash by the shadow. Center the bright image on the card and focus — chances are there will be a number of spots on the surface. To record your daily sunspot observations, draw several 6"-diameter circles on a piece of paper — one for each day. Use the observations to estimate the solar rotation period for yourself. Soon a picture of the changing sun will be your reward.

The number of sunspots varies over approximately an 11-year cycle. The last peak was around 1990, with the next one expected about 2000. The increase in activity is usually quite rapid toward a sunspot maximum.

Once the sun descends below the horizon, **Mercury** will make a brief appearance. In early July, the tiny planet will be visible in the slowly darkening twilight. The situation improves as Mercury approaches its greatest eastern elongation from the sun (26°) on July 16/17. Unfortunately, this later setting time brings with it a dimming of magnitude. Mercury starts the month at a respectable magnitude –0.3 but ends July at magnitude 1.6.

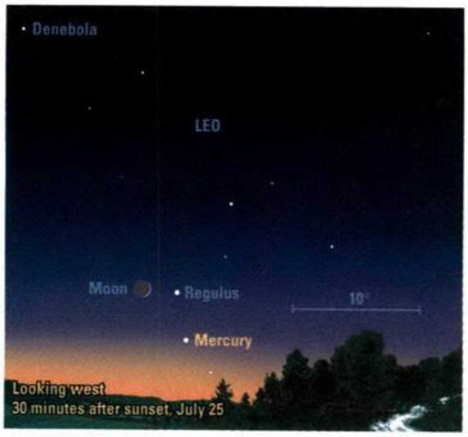
Early in the month you can use the 1st-magnitude duo Castor and Pollux to find the elusive planet. The pair rests slightly to the right of Mercury, but take care not to confuse either star for the planet. Once the sky has darkened, the 1.3-magnitude star Regulus in Leo the Lion may be visible to the far upper left of Mercury. On July 1, Mercury sets roughly 90 minutes after the sun. On July 5, Mercury crosses in front of the Beehive Cluster (M44) in Cancer, but the cluster will be invisible in the bright sky. By July 25, a lovely two-day-old crescent moon lies 3° to the left (southeast) of Regulus. Look for Mercury shining just 3° below Regulus. On this evening, the sun sets exactly one hour before Mercury.

No other bright planets appear in the evening sky until later in the night. Before they rise, spend time looking at the summer sky and its splendid sights. Mighty Hercules passes through the zenith by 11 p.m. It carries with it the finest globular cluster in the Northern Hemisphere, the Hercules Cluster (M13). Adjacent to Hercules is the delicate shape of Lyra the Harp with its brightest star, Vega. Nearby are the stars Sheliak and Sulafat (Beta [β] and Gamma [γ] Lyrae). The Ring Nebula, M57, can be found here.This famous little smoke ring was thrown off by its parent star thousands of years ago and is a relatively easy target in a small telescope. Look for it roughly midway between Sheliak and Sulafat.

Vega is one of the brightest stars out at this time and is one of the three stars that make up the Summer Triangle. The others include Deneb to the east and Altair to the south. All three lie in the midst of the Milky Way. Deneb's parent constellation, Cygnus the Swan, contains the best example of a Milky Way rift. From a dark site, the Milky Way appears to be split into two distinct parts down the length of Cygnus. This dark lane is caused by dust that is located between us and the more distant stars. Follow the faint band southward, notice how the Milky Way begins to fatten. The broadest section can be found in the region of Sagittarius and Scorpius. From mid-northern latitudes (around 40° north) these two summer constellations are easily seen. At higher latitudes, they become more difficult to find — the stars rest in the haze that hugs the horizon.

Mercury's Evening Stretch

In complete contrast to the morning series of bright planets, Mercury stands alone in a relatively favorable evening position. It is your best chance this year to observe the planet's changing phase in shirt sleeves — provided the mosquitoes don't get you.



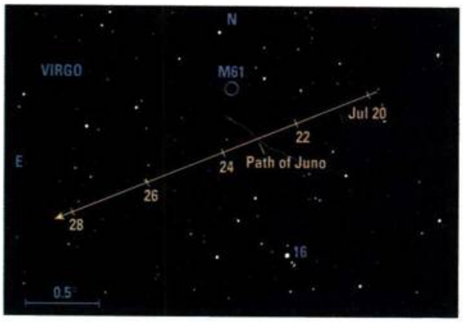
Looking west
30 minutes after sunset, July 25

Mercury changes from a fat gibbous disk to half a crescent by month's end. Try to notice its gradual increase in size as the month progresses.

The first part of July finds Mercury perched a steady 7° above the west-northwestern horizon as the bright evening twilight begins to fade. At magnitude 0.2, it's more obvious than Mars was last fall and winter. By July 20, Mercury has traveled eastward enough to be in the same binocular field as bluish-white Regulus. Take time to compare their similar brightness and contrast their colors.

The slender crescent moon adds interest on July 25 as it slides 1° south of Regulus. Binocular observers can see it mimicking Mercury's phase.

Juno in Galaxy Country



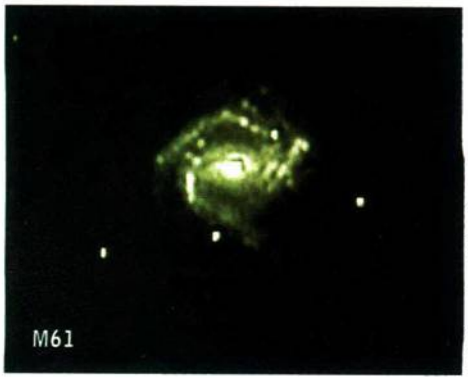
Asteroid 3 Juno gathers steam after its apparent standstill in May. It also makes a brief appearance in one of the larger galaxies of Virgo the Maiden.

Only 150 miles (250 km) across, Juno is the smallest of the "big four" asteroids discovered in the early 1800s. Because Juno is approaching aphelion (the far end of its elliptical orbit), its magnitude fades past 11 this month.

Juno's subtle light requires a careful star-hop to find and identity. Try making a sketch of the starfield one night and see which "star" moved when you revisit it the next. One easy way of doing this is to bring along a star chart. Use software that plots the asteroid's position against much fainter stars — but remember, some electronic catalogs are not complete. There may be gaps or errors in the star positions your program plots, so be careful in your identification.

Juno masquerades as a "guest supernova" in front of the mighty galaxy M61 in Virgo from July 23 to 25. It's perfect timing with a new moon on July 23. You'll find Juno less than 30' from M61.

There's also 22 Kalliope nearby. Glowing faintly at 12th magnitude, Kalliope slides 3.5° southeast of the galaxy M49 on these nights. You'll need your own chart for this one.



M61

John Chumack and Glenn Gombert

Saturn at Its 3-D Best

Mark Schmidt

Saturn presents its most fantastic face when its globe casts large, strong shadows onto the rings. These shadows naturally allow the eye and brain to reconstruct depth into an image.

On July 26, Saturn produces maximum shadow when it arrives at quadrature — 90° from the sun with respect to Earth. The rings are in a good observing position as well (tilted 16° to our view), and the planet's south pole is visible.

At the end of your all-night observing sessions, give Saturn the time to impress you with its detail. Note the dark Cassini division splitting the rings, and try to spot Encke's gap near the outer edge.

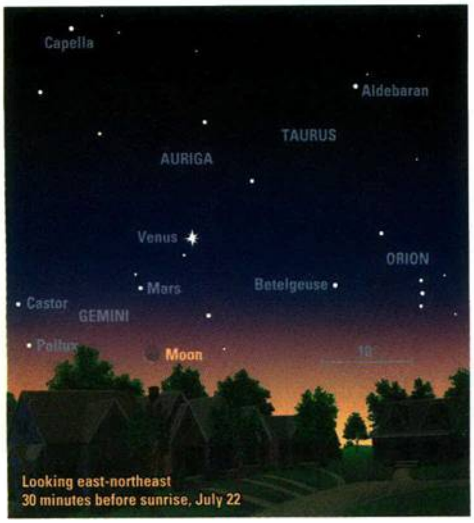
For the truly ambitious, here is a daytime challenge. Saturn is in the sky's polarization band (see last month's Jupiter's Daylight Delight, page 75) at month's end. Polarized sunglasses darken the daytime sky while letting Saturn shine through. They offer you a chance to see the planet without magnification in daylight. On the morning of July 17, Saturn can be found 3.5° northwest of the last quarter moon. Use binoculars to show you the spot first, then try seeing it with your polarized sunglasses.

Old Moon, Young Day

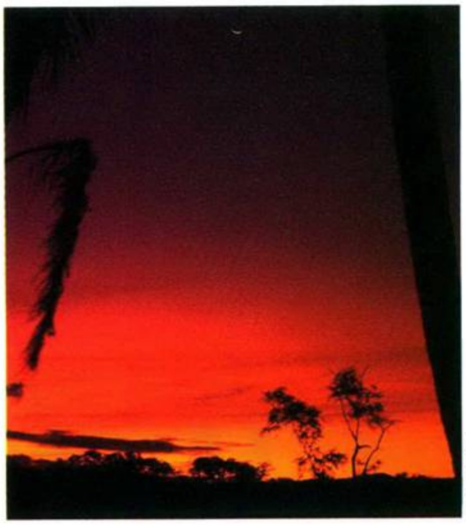
It's always fun hunting for a vanishing moon. The breathtakingly sharp crescent is a beautiful sight to behold. On the morning of July 22, the old waning moon will be 28 hours away from its rebirth for those on the east coast but only 25 hours for those on the west.

To qualify for this personal challenge, those living at latitude 40° N must be up by 4:45 a.m. The farther north you live, the earlier you have to awaken.

Unlike last month, Venus and Mars act as guideposts to the moon's thin crescent. To find the moon, start by looking for the planet Mars. It will be hanging to the lower left of blazing Venus. Mars is pretty diminutive (a 1.6-magnitude pale orange spot), but it will be a cornerstone for hopping down to the moon. Start by traversing nearly the same distance down from Mars as the space between Mars and Venus — a bit more than a binocular field apart. Try to see the crescent with your naked eye first.



Looking east-northeast
30 minutes before sunrise, July 22


Larry Landolfi

For the planetary sleuth who likes a challenge, **Pluto** remains a potential target. The 14th-magnitude planet lies northwest of Zeta (ζ) Ophiuchi. Wait until midnight to catch **Neptune** and **Uranus**. These two are easier planetary challenges than Pluto. Neptune is in Capricornus and rises by 10 p.m. The planet lingers to the north of the dim 9th-magnitude globular cluster, M75. Neptune reaches opposition on July 23. The 7.8-magnitude bluish globe is a challenge to identify with binoculars, but a telescope at high magnification will reveal its slight 2"-diameter disk.

Uranus rises 40 minutes later than Neptune and is much easier to spot. Shining at magnitude 5.7, Uranus reaches opposition early in August. Opposition is the time when these planets lie exactly opposite the sun in the sky as seen from Earth, and it represents the best time to see the more distant planets. This month you'll find Uranus slightly less than four moon-widths (2°) southwest of Theta (θ) Capricorni. It has an angular size of 3.7".

By the time Uranus is due south, **Jupiter** will rise above the eastern horizon. This planet's sheer brilliance is unmistakable. At a dazzling magnitude –2.6 on July 1, Jupiter brightens two-tenths of a magnitude as July progresses. Nestled in the dim stars of western Pisces, it seems even more dominant. You may be surprised to know that binoculars will unveil the moons of Jupiter — if the binoculars are securely mounted on a tripod to prevent that inherent shake of the human hand. Telescopes reveal the delicate beauty of the jovian

OBSERVER'S CHALLENGE: Pluto

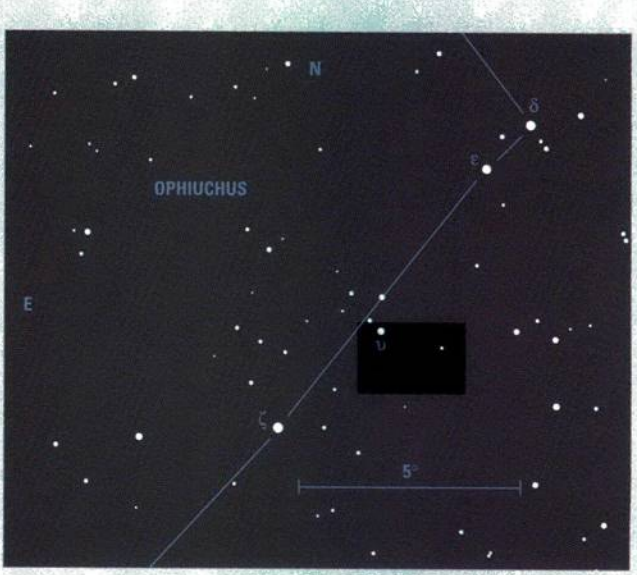
Enigmatic Pluto draws us all to the eyepiece. Though the debate over its planetary status continues, finding this far-off solar system object has been a challenge sought by many. For some amateurs, a Pluto search has become an annual ritual. For others, glimpsing its feeble light means creating a treasured memory.

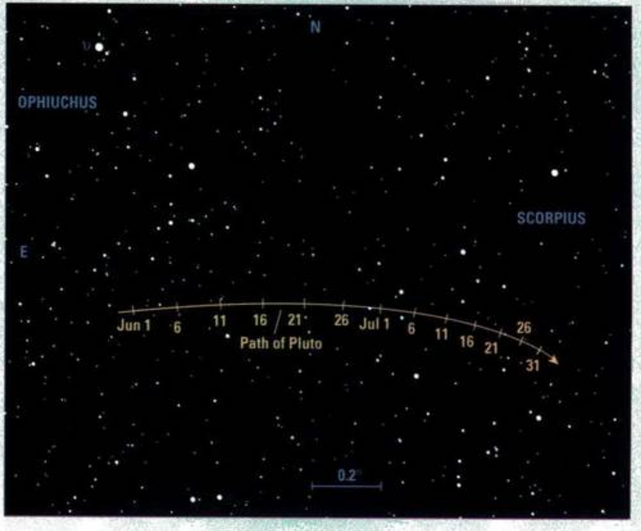
Pluto just passed opposition at the end of May. This means the planet is available in the evening sky. Start your search at Zeta (ζ) Ophiuchi, the bright middle star in the row of three at the bottom of Ophiuchus. Move up to the northwest to reach Upsilon (υ) Ophiuchi, then slide southwest to the area where Pluto hides. If you can't find your bearings, there are two stars in a line that head off from Upsilon. These two are in the opposite direction from Pluto. Use them to slide back through Upsilon and toward Pluto. The planet is nearly the same distance away from Upsilon as is the pair of stars — almost a degree.

With Pluto at magnitude 13.7, you should be able to spot it with an 8-inch scope from a dark site. Once you become familiar with the field at medium power, crank up the magnification past 150x. An even higher power is better still, if the night is steady. Such high magnifications will darken the background, helping Pluto be more than just a faint flicker.

The best way to confirm an observation of Pluto is to look for it twice. You may want to sketch the field with stars as dim as 14th magnitude. Use the second observation to see which star has moved against the distant background stars. A broad "V" shape of 8th- to 9th-magnitude stars can be used to anchor your sketch.

On the evening of July 22, Pluto pretends to be the fainter companion to a 13th-magnitude star. The planet is a mere 15" north. To see the pair, use a star chart that plots stars as dim as magnitude 15. For the experienced observer needing an even greater challenge, mask down your scope and try to pick up Pluto with less than 4 inches of aperture.





cloud systems. Frequent observation of the planet will also show their motion. Jupiter rotates so rapidly (once in less than 10 hours) that cloud features will move noticeably across its surface in a period of an hour. Jupiter turns toward its retrograde loop, slowing its easterly progress to a halt, on July 18. Two months later it reaches opposition. Between now and December, the apparent diameter of Jupiter will not shrink below 40". During July, it grows 4" ending the month at 46" across.

On July 14, the waning last quarter moon lies to the west of Jupiter. On July 15 it will be east of the planet. A few nights later, on July 17, the moon lies 2° south-southeast of **Saturn.**

Saturn is twice as far from Earth as Jupiter during July. At its distance of 9.4 astronomical units (860 million miles) on July 15, Saturn appears to be half the apparent diameter of Jupiter or about 17.6" across. Both planets are relatively similar in physical size — Saturn is nearly 16 percent smaller than Jupiter. Saturn, however, makes up for its subordinate place by displaying a spectacular ring system whose breadth across the long axis approaches the apparent size of Jupiter. Saturn's rings also contribute to its 0.4-magnitude brightness. The planet wanders into Cetus the Whale during the last week of July. Though Cetus is not a zodiacal constellation, Saturn reaches it due to the planet's 2° orbital inclination relative to the ecliptic. This orbit can occasionally take Saturn more than 2° south of the ecliptic.

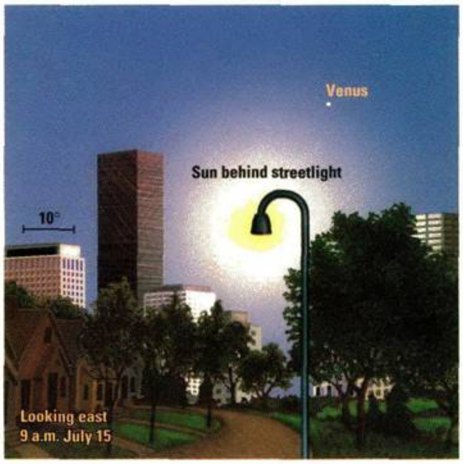
During the first few days of July, **Venus** rises nearly two hours before the sun and shortly before Aldebaran *in Taurus the Bull.* As the month progresses, it rises later each day, temporarily joining Aldebaran and the Hyades star cluster. Venus outshines Aldebaran by nearly five magnitudes (–3.9 vs. 0.85), and the twosome, along with the Hyades, makes a beautiful predawn sight. Through the course of the month, Venus falls back toward the solar glare. It moves slowly at first, but by mid-July Venus is within a degree of the lower horn of the Bull, marked by Zeta (ζ) Tauri, and actually passes very close to the Crab Nebula.

While Venus moves ever closer to the sun's glare, you can also watch **Mars** emerge from it toward month's end. Start looking for the Red Planet early on July 21. That morning a crescent moon, two days before new, passes 4° south of Venus. Mars can be found double that distance to the east of Venus, shining at magnitude 1.6. When the last day of July arrives, Mars and Venus are less than 3° apart in Gemini. Our closest planetary neighbors are moving toward a conjunction in early August. Mars is also beginning its slow climb to opposition in April 1999, but you'll have to wait until the end of 1998 to begin seeing Mars well through a small telescope.

Our own planet reaches a benchmark this month. Earth is at aphelion (its farthest point from the sun) at 8 p.m. EDT on July 3. The sun will be 94,509,000 miles away, almost 1/30th farther away than its perihelion (closest point to the sun) distance in January.

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

Daylight Damsel Sightings



Our sister Venus rules the dawn sky. There's nothing like this blazing white magnitude –3.9 beacon anywhere else in the sky. But July's dawn is too early for most observers — so why not hone your daytime skills?

You don't need setting circles to find Venus. Head out at lunch time and hide the sun behind a streetlight's lamphead. Remember to pay close attention to where you are standing. The next day, go out during your coffee break. If you time it right, Venus should be quite close to where the sun was the day before.

For this trick to work, you must carefully note the time you observed the sun's position behind the lamphead. The next day, subtract the times that follow. On July 1, Venus passes through the sky two hours and thirteen minutes ahead of the sun. By July 15, it's two hours and two minutes earlier, and on July 31 it precedes the sun by one hour and forty minutes. There's an added twist: Venus slowly changes altitude relative to the sun. On July 1 it's 2.5° lower than the sun, by July 15 it's 1° higher, at month's end Venus is 4° higher than the sun.

A challenge for those with a telescope occurs on July 2. After you center Venus, drop 4° south to pick up Aldebaran. Dobsonian owners can slide straight down when the pair transits at 10:30 a.m.

The Zodiacal Band

Zodiacal light comes from sunlight scattered off of dust grains that line the ecliptic plane of our solar system. It appears as a large, faint pyramidal glow whose base is on the horizon after the twilight glow has faded (see photo). This form is best seen on spring evenings and mornings in October.

A fainter incarnation of zodiacal light stretches clear across the sky along the ecliptic (the orange line on our sky maps). Because city lights overpower the glow, the vast majority of amateurs will only get a chance to see the zodiacal band at a star party, where the skies are usually quite dark.

Jerry Lodriguss

Observing the band is one of those funny things. You generally don't notice it until someone points it out, then — under a dark sky — it's fairly straightforward to see. Keep in mind that it's fainter than the Milky Way.

One way to detect the zodiacal band is to watch for the sky background brightness to change as you slowly scan up from the horizon. Initially you'll see a brighter horizon haze followed by darkness, then the sky will brighten a bit — this is the zodiacal band — only to fade as you look higher. You might have to block the light from Jupiter with your hand.

Once you recognize this faint belt, you'll notice that Saturn clearly lies beneath it, as shown on the Path of the Planets map (page 69).

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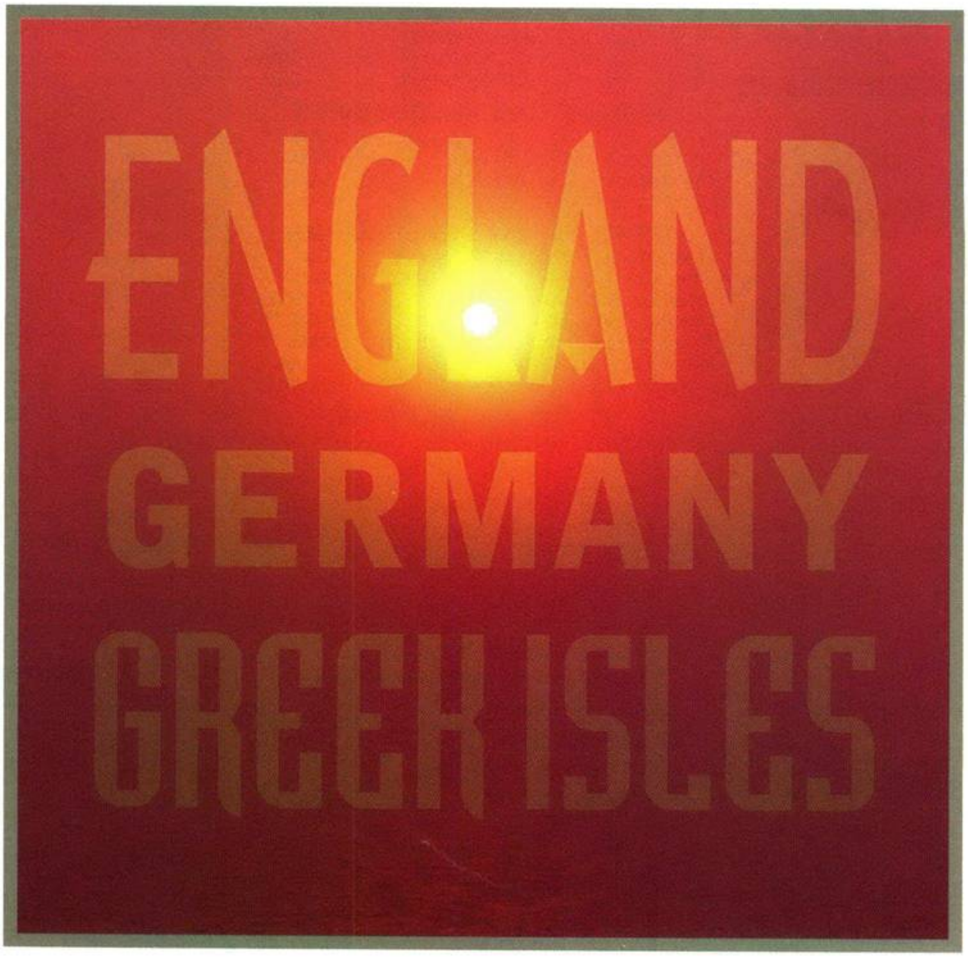

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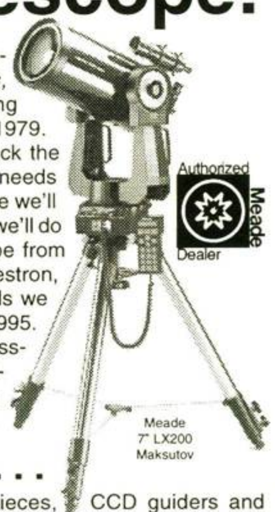

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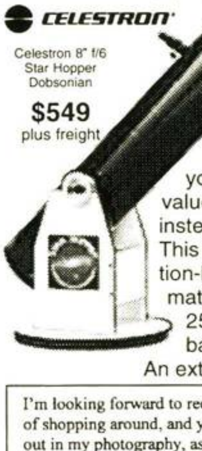

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SEEING

YOU DON'T HAVE TO BE AS COLORBLIND AS a beagle to cock your head quizzically at the night sky. Color is a puzzling, tricky business. At first glance the heavens seem a simple study in black and white, a monotony of white stars splotched upon a black background. The metallic, monochrome moon emphasizes this vapid impression. Worse, our nocturnal vision uses the eye's colorblind rod-shaped receptors instead of the full-spectrum cones that operate in bright light. It's easy to understand why astronomical language is not particularly colorful.

Yet only a few moments of sky-study let us step away from neon expectations and start thinking in pastels, allowing long held astronomical myths to vanish like tax refunds.

When it comes to color, we see that nature is hardly impartial. Instead, the universe has a favorite; a single shade keeps recurring like a catchy jingle, pervading all of time and space. But before we play favorites, let's stroll the night's alleyways and explore the surprises of its true tints.

Start with the naked eye. As you comparison-shop from star to star, pigments become obvious. Beginners, who assume "red giants" like Betelgeuse or Antares must actually appear red, are quickly disillusioned. More seasoned skygazers realize that even the ruddiest bright stars would fall just slightly on the orange side of yellow if we could take them to a paint store and match them with a color chart. A few dimmer stars such as Mu (μ) Cephei, high in the north these nights, display a deep orange when seen telescopically. Compared with blue-white suns such as Rigel, the contrast is vivid. Indeed, stars come in almost every color with one major exception: green.

THE MISSING **EMERALD**

A few reference books list some binary star members as green, among them the famous "emerald" companion to Antares. But after looking at a truly green object, such as a planetary nebula or Uranus, you wouldn't invite any into the St. Patrick's Day parade. It may be that after gazing at a bright reddish star, the eye merely projects the complementary color on its white companion, just as we see a hallucinatory green blob floating in the air after we've stared at a stoplight while waiting for it to change. Evidence that this is indeed the case occurs when the moon eclipses the brighter

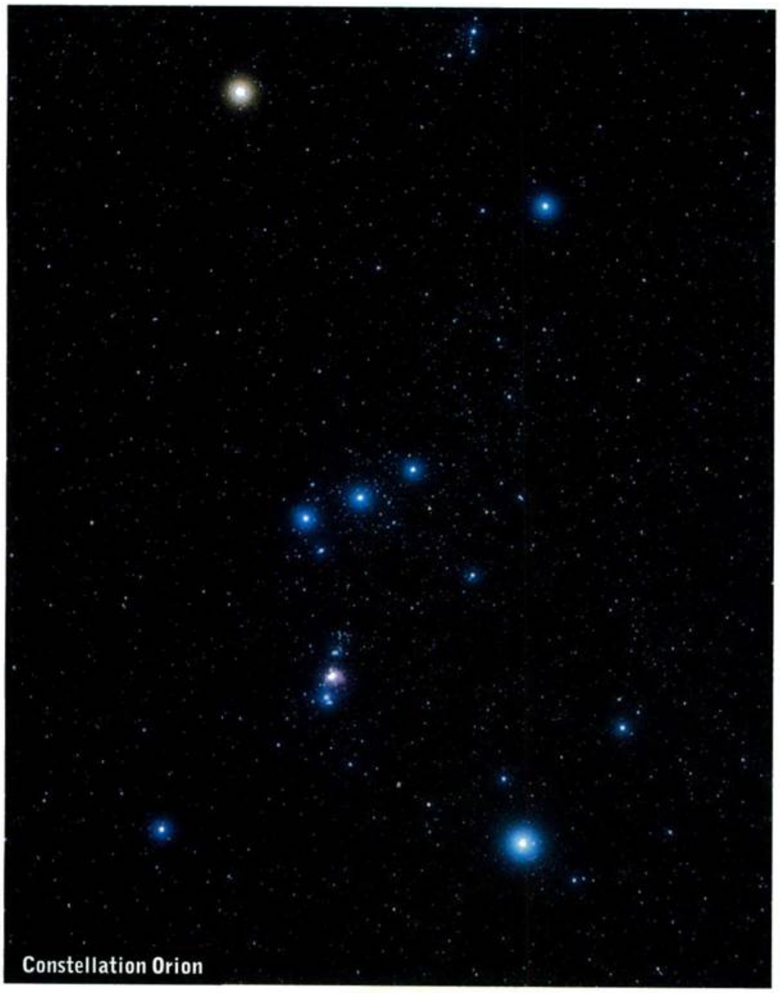
Rho Ophiuchi Region

RED

Though it seems at first a simple study in black and white, the universe blazes with color.

by Bob Berman

Bill and Sally Fletcher



John Chumack

Constellation Orion

member of the pair and leaves the dimmer, supposedly green companion alone for a few moments. Its alleged green hue disappears.

There are green meteors, and the aurora borealis is predominantly a pale lime, so there are plenty of green pastures in the night sky. And even though it can't be seen, a torrent of green light cascades from all stars — along with violet, red, and everything in between. It doesn't take a Krell IQ boost to grasp why so many suns appear white or nearly so: When a phalanx of various colors arrives at our eyes simultaneously, their colors are scrambled together like an omelet; the combination is perceived as white. (In the mixing of paints, the opposite effect occurs — the combination of all colors produces black. This contradictory result happens because with paint, the pigment's color comes largely from its ability to absorb various

Betelgeuse

John Chumack

Alan Dyer

Square of Pegasus

shades. Mix too many together and all colors get absorbed. Voilà: black.)

As a simple spectroscope reveals, even colored stars emit a full rainbow's spectrum of hues; stars that seem reddish merely boast a slight excess of that tint. We don't see green stars because you'd need both the violet and the red ends of the spectrum to be suppressed so that only the middle, green portion dominates. That just doesn't happen.

STELLAR EYE CHART

Of course, color also won't appear if the star is too dim. See for yourself where your eye's color cut-off begins; That's the point at which the retinal army of rod-cells takes command. I've personally always had an easy time perceiving color in 2nd magnitude stars but find 3rd magnitude unvaryingly white. The Great Square of Pegasus is an ideal place to test your own vision during this autumn season. The upper rightmost star, Scheat, is a red giant, while the upper left star, Alpheratz, is blue-white; following this line to Mirach in Andromeda gives you orange again. Can you perceive such tints in these 2nd magnitude stars? If not, wait 'til later when Aldebaran and Orion's stars rise, providing you with easy first and even zero magnitude color contrasts. (If you still see no color, then you may have Canine Ocularia, a genetic disorder caused by your ancestors having somehow acquired dog chromosomes. Scratch your stomach and see if your leg twitches.)

Once you establish where your color vision cuts off, you can predict which telescopic objects will appear in color. For example, if your scope is large enough to reveal 14th-magnitude stars, it means (since the unaided-eye barrier is 6th magnitude) that its optics brighten stars by eight magnitudes. If magnitude two is your personal naked-eye color limit, you simply add eight and bingo: Expect 10th magnitude stars to appear in color through your instrument while everything fainter will be monochromatic.

Even binoculars, which typically boost brightness by three magnitudes, dramatically raise the curtain on previously unseen colors. A good example now rising in the east is the Pleiades star cluster, whose main naked-eye members glow at 4th and 5th magnitude and therefore appear colorless to the naked eye. Because binoculars make them seem to shine at 1st and 2nd magnitude, the hot, striking, blue-white tint of the Seven Sisters now becomes instantly obvious.

But if we try to see too deeply into the blue or red end of the spectrum, color vanishes once again. Humans vary in how far we can peer into the extremes of the color palette before our eyes become insensitive. For this reason, detail beyond the black Balmer delta absorption line that lies buried deep in the rich violet end of many stars' spectra is seen very easily by some, while it remains invisible to others.

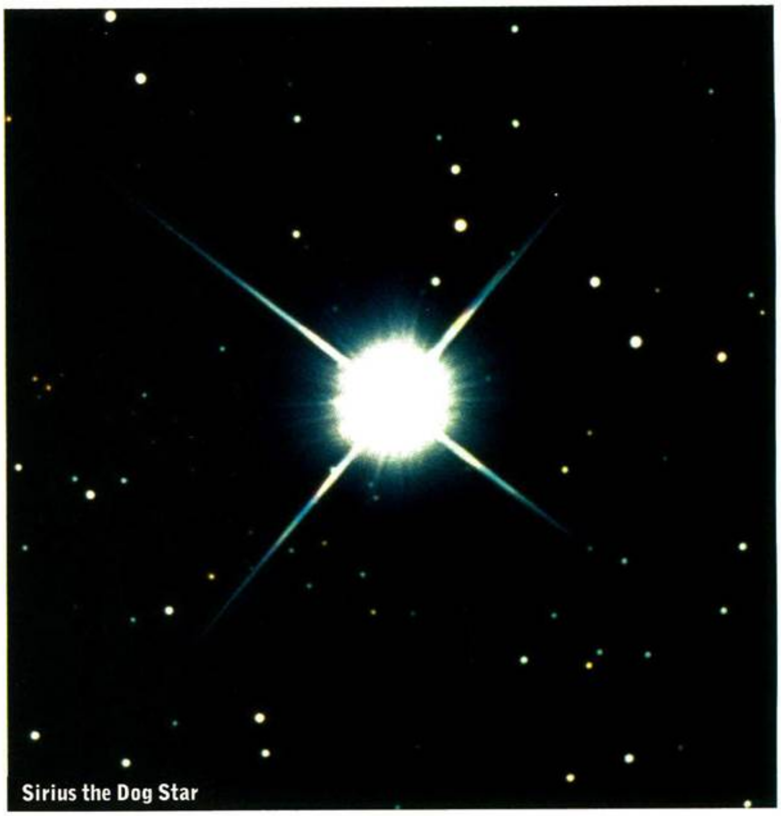
Another problem with color is that it's subjective. Like witnesses at an accident, people report colors differently. For proof, turn your telescope to Cor Caroli, near the end of the Big Dipper's handle. Any telescope at 100x shows it as double and reveals the brighter component as blue-white. Easy. Now ask people to identify the pastel shade of the dimmer "B" star, the companion, and see what happens. At our observatories, responses from hundreds of students, colleagues, and friends have ranged from gray to blue, purple, amber, and yellow. I've always seen it as a pale lilac, but the majority has ruled otherwise. There's never a consensus with this or many other stars. Like pizza or beauty, there's no objective rating system, no appeals court of color arbitration. It's a free-for-all; assign any color to any celestial object without fear of being "wrong."

Then there's the problem of the eye's differential sensitivity at low light levels, which is astronomy's challenging arena. At the margins, some hues may appear faintly while all others have changed into shades of gray. This is one reason some nebulae, such as M42 in Orion, look pale green at the eyepiece yet their photographs display no green whatsoever.

PIGMENTS OF IMAGINATION

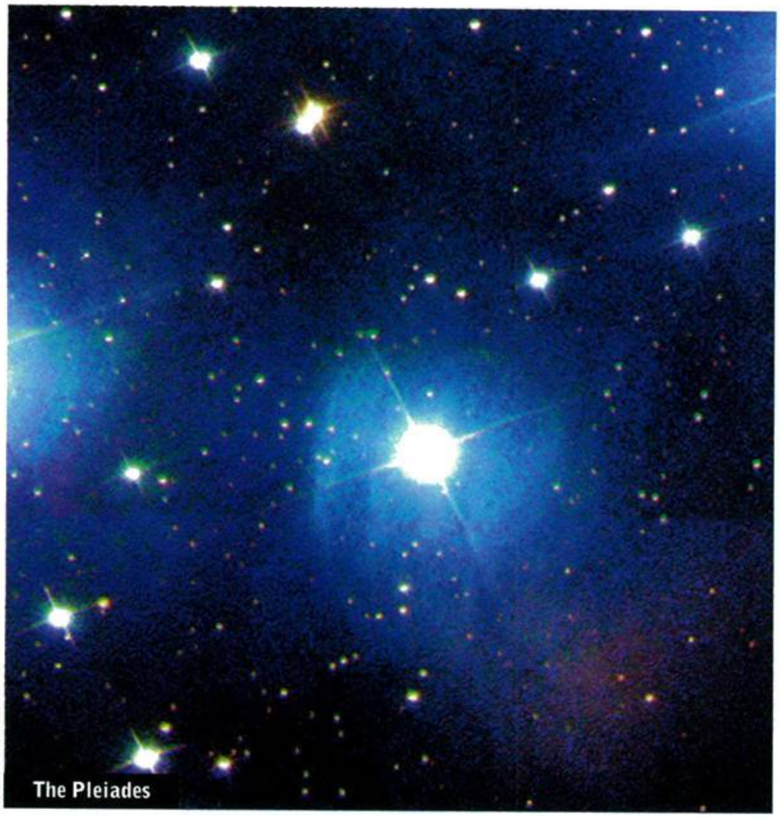
Astrophotography, whose images grace the pages of textbooks and magazines such as this one, gives us our greatest sense of the colors of space. Unfortunately, those impressions are almost always wrong, or at least skewed.

First off, each film has its own bias and will falsely emphasize certain wavelengths because of the chemical emulsion of the film. Then you've



Sirius the Dog Star

John Chumack


Gregory Terrance

The Pleiades

got reciprocity failure: Long exposures stop capturing color truly and effectively, a deficiency that is not uniform across all parts of the spectrum. Result: More color bias.

Then there's overexposure and underexposure of differing parts of a nebula, explaining why that green-looking central region of the Orion Nebula appears a burnt-out white in photographs. At the same time, those beautiful sweeping gull-wings at the outskirts of the Orion Nebula, which merely look gray visually, now take on breathtaking blues and crimsons.

So which is the nebula's "real" color, the telescopic view or the photographic one? Neither. If you could journey the 1,500 light-years and see it sufficiently brightly so that your cone cells all fired at will like cannons, as if you were staring at a sunset, the Orion Nebula would look different from anything we have yet experienced.

Disillusioned yet? We're not finished. There's still the increasingly popular pastime of manipulating the final product — easier than ever with computer programs. Why settle for Neptune's true pale aquamarine when it's easy to crank up its saturation and deliver a dramatic but spurious image? Of course, our science agencies wouldn't do such a thing, would they?

Since the early 1980s, NASA and JPL have seemed unable to resist such temptations. Few pictures they release to the press (and thence into our textbooks) have not been tweaked, big-time. Even fewer have captions acknowledging that they are "false color." Sure, if Saturn's rings are presented in five neon tints, the "false-color" statement is made. The problem is, they only confess when it's pretty obvious that someone's hand has been in the Adobe cookie jar. A greatly green-ified Uranus, much less likely to be detected by laypeople, gets released as is.

Jupiter's Red Spot? I haven't seen a "true-color" version in decades — have you? Instead, that pale pink storm almost always shows up as fire engine crimson. In fact, that whole giant planet, viewed in any textbook or magazine, is a psychedelic study in vivid swirling yellows, oranges, and reds. Have you ever wondered why Jupiter doesn't look that way through your backyard telescope? Because it doesn't look that way, period.

Jupiter is so bright and obvious these nights that in steady viewing conditions, looking through a good reflector telescope using a high quality eyepiece, you are really observing the giant world's true colors. Note that its similarity to all the photos you've seen is close to zilch. Apparently NASA believes the public can't handle the fact that the jovian planets are globs of hydrogen, not lava lamps. Or perhaps they simply enjoy the hubris of touching up the planets in a kind of one-upmanship on nature.

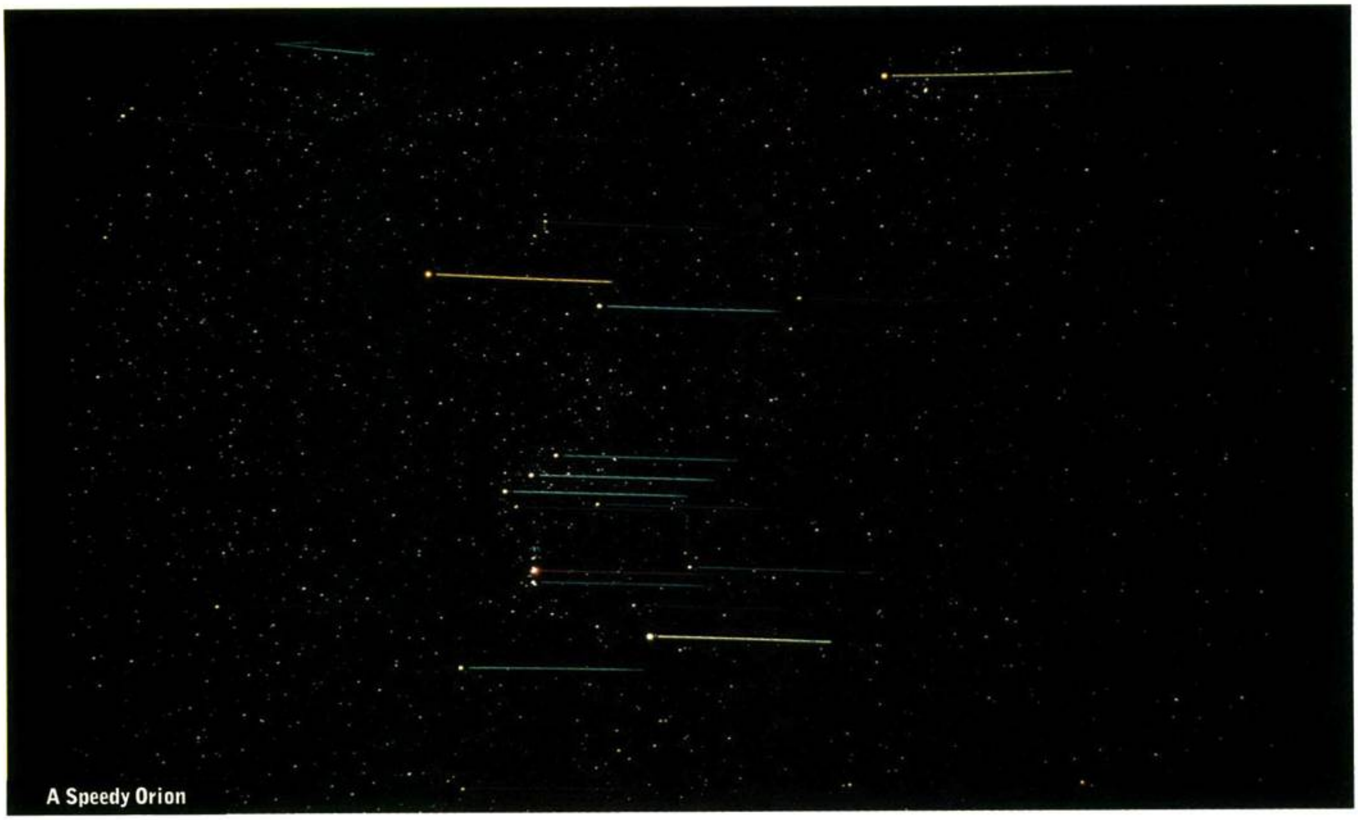
Venus, too, is usually portrayed as being either uniformly (take your pick) light blue, orange, yellow, or brownish. In reality, our sister planet's clouds are composed of pearly white sulfuric acid droplets, not carnival spray paint. See it for yourself: Venus is so brilliant (check it out in the southwest right after sunset) that its actual color is obvious to the naked eye. White. Or let that spectroscope allow you to discover that Venus is really emitting a full range of spectral colors — which is really no surprise since those ultra-shiny clouds are merely reflecting sunlight.

(But before we sue NASA for defamation of planetary character, one must concede that the enhancement or addition of color emphasizes subtle detail and delivers the not-so-subtle benefits of winning public and congressional enthusiasm for further explorations.)

NATURE'S CHOICE

With all this, one wavelength of light does manage to predominate. If our eyes were sensitive to ultraviolet, it would be the shade we'd see most often; the one emitted whenever hydrogen, the most abundant element, has its electron plunge to its lowest energy state. But humans can't see that, so let's skip to the most common color that we can see — also caused by electrons jumping like fleas.

Hydrogen's single electron will readily leap from the second orbital state up to the third whenever it gets goosed by a bit of energy. But it can't wait to fall back again, and when it tumbles it emits light of exactly 6,563 angstroms wavelength. This goes on without variation throughout the universe and has been performing like a repertory play for the past 12 billion years. Talk about long running shows.


A Speedy Orion

Bruce W. Shier

The Great Uranus

Gregory Terrance

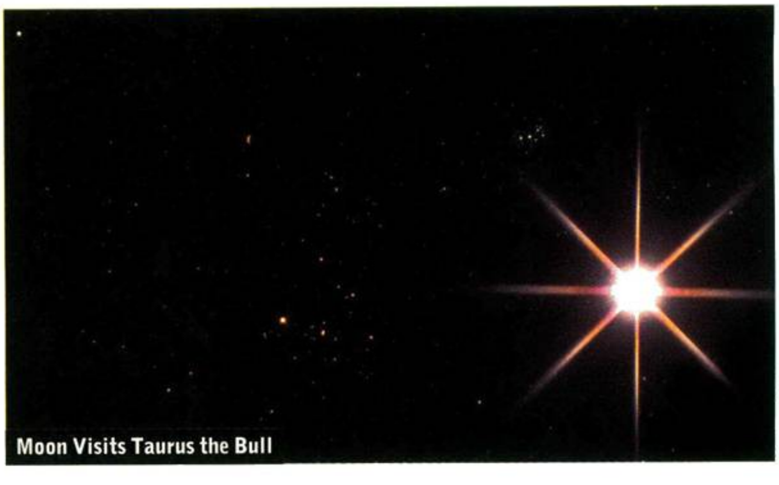
Andromeda

Stephen Walther

So we come to the most common color in the cosmos. We find virtually none of it in our own solar system, but never mind. Look instead at photos of nebulae and you'll realize that the shade recurs like a haunting melody. It's a beautiful deep red — brushed onto every emission nebula, woven like a brocade into spiral arms of every galaxy.

Matching the vibrancy of our blood and the beauty of our roses, it's more than merely genuine; it's the dominant color of the universe. ■

Bob Berman is Director of Overlook Observatory near Woodstock, New York, and Storm King Observatory in Cornwall, New York. His previous article for Astronomy was "Mastering the Mysterious" in the June 1998 issue.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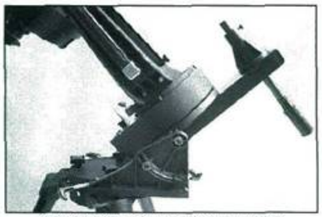

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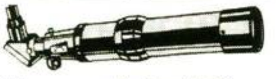

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It's a Bird. . . It's a Plane. . . It's a Satellite

Be they faint streaks or brilliant flares, satellites offer an observing passion to many.

by Nancy L. Hendrickson

In 1973, a group of ten 6th graders, their parents, and teacher met in the predawn darkness to watch the flight of an unusual bird. At birth, it was crippled and weighed as much as the New-World-seeking Santa Maria, but on it flew. Finally, one of the kids shouted "There it is!" Soaring above was America's first space station, Skylab. Today, one of those kids still scans the sky as a member of the rapidly growing global community of satellite observers. For Tom Smith, the memories of that long-ago morning are vivid.

Since Sputnik I's launch in 1957, thousands of satellites have circled Earth, unintentionally creating a new hobby. For those who love chasing "space birds," satellites are collected as ardently as Messier objects. But unlike Charles Messier's catalog of 109 objects, satellites offer more than 8,000 potential targets — there's something for everyone. Manned space vehicles are by far the brightest targets in the sky. The Space Shuttle can glow as brightly as Venus, with Mir appearing to be a speeding Jupiter.

Although astrophotographers curse the bright slashes satellites cut through their pristine photos, sats are here to stay. They keep track of our weather, study our oceans, investigate solar flares, facilitate navigation and communication, and snoop on others. Some of the brightest moving lights are the weather-tending NOAAs, the ocean-trawling SeaSat 1, the Hubble Space Telescope, and the Russian COSMOS. The Iridium communication satellites are lighting up the observing community with spectacular (and predictable) flares of up to magnitude –5 (the brightest star for Northern Hemisphere observers is Sirius, at a paltry –1.5).

Like Smith, I got hooked on satellite observing several years back. During a late spring night under the dark skies of Colorado's Mesa Verde, I shared the edge of a parking lot with a fellow stargazer. While he used his Schmidt-Cassegrain telescope to pick off the Virgo galaxies, I stood rooted for the longest time, just staring at the sky. We city dwellers sometimes go numb when reacquainted with darkness. Occasionally, though, a light way, way up in the sky caught my eye as it sped against the stars. I knew I wasn't seeing an airplane, but what was it? After the third or four pass, I realized I was watching sunlight reflecting off high-flying satellites.

When I got home I began researching ways to identify the satellites I had seen and predicting how to see more. It didn't take long before my computer was spitting out sat tracks like a pro.

Not that many years ago, calculating satellite orbits wasn't so easy. Leo Barhorst, observing from the

Sunlight hitting one of the three Teflon-coated *Iridium* satellite antennae reflects back to Earth with a brilliant flash or flare on September 20, 1997.

Chris Dorreman

Netherlands, recounts joining the Dutch Working Group Satellites in 1975. Using orbital information mailed by NASA, he spent afternoons hand-calculating predictions. Much too often, the hours of work were an exercise in frustration, as clouds arrived along with darkness. Today, using a personal computer, a satellite's track can be calculated in seconds. Now when clear skies arrive, Leo runs a prediction program, sets up his laptop in the backyard, and settles in for an evening of space birding.

The Internet has made it simple to join the satellite observing community, particularly through the pages of the Visual Satellite Observers (VSO). The entire site is a tutorial in satellite watching, from factors which affect visibility (altitude, brightness, inclination) to an explanation of why some satellites flash. There, too, you'll find definitions for common orbital terms and a lesson on making position measurements. If you want to see what a satellite looks like through your telescope, the VSO will tell you how to do it. There is also a section on Iridium communication satellites and links to software that predicts Iridium flares — a brilliant flash caused by one of the three main mission antennae.

Jeff Hunt, one of the VSO Home Page producers, has written a detailed file, An Introduction to Satellite Observing, which is close to being a mini course book for new observers.

Tracking Those Birds

A simple way to see your first satellite is to use one of the many online prediction services. Enter the date and time you want to observe, along with your longitude and latitude, or closest city, and the site will spew out a list of sats above your hometown. Some services only predict passages for a short list of bright satellites or Mir. If you have a specific satellite in mind, the service may not include it in its database. While the services are a good place to begin, their resources are limited. Once you've gotten a taste for tracking down these speeding lights, chances are you'll want to run your own predictions. Here's how.

To accurately predict a satellite's passage over any given location, you'll need tracking software and current orbital data or orbital elements. Although not a complete list, the programs you're most likely to see are SatSpy, WinTrak, Traksat, WinOrbit, PC-Track, Micro Orbiter, and OrbiTrak for Mac. Most are commercial or shareware. Although the bells and whistles vary, the mechanics are the same: Load a set of orbital elements and stand back. In a matter of seconds your software will generate the celestial coordinates, range (generally in kilometers), and angle of elevation for any satellite in the element file that meets user-defined criteria.

William R. Dellinges

The Hubble Space Telescope streaks across the Arizona sky on April 20, 1991.

On November 9, 1997, five Iridium satellites were launched. The Delta II missile's exhaust plume and contrail catch the sun's light, while Earth's surface bathes in twilight colors.

Brian Webb

Your software's output comes in different forms. Some are text-only, some plot a satellite's track through a starfield or show a 3-D representation of the orbit as seen from space. One of them, SatSpy, prints an observation form showing the track through the constellations, with room below to add your own comments.

The element file you pick will determine the available satellites you can view. You can, of course, download the whole enchilada — elements for more than 8,000 objects. There are element sets for just about every combination of objects you can imagine — the brightest 100, weather sats, communication sats, spy sats, navigation sats, newly launched sats, the Iridiums, and others. You can edit element files to add in any particular favorite of your choice.

Time to Observe

Once your software has printed a list of potential targets for the evening (or early morning), what next?

Get organized. More often than not, the list will contain several targets that *pass the same star* within minutes of each other. Make sure your print-outs are in chronological order or you'll certainly miss a pass. You'll also want to group objects that fly through the same part of the sky. It's far more difficult to acquaint yourself with the starry background in the north and then have to whirl around in a moment to try to find something coming in from the west.

Whatever your interest; have a master plan. You may be the kind of person who wants to see every single satellite cutting through space, or maybe just the bright ones. At present, I'm hooked on chasing Iridium flares. Marco Hahn, observing from Germany and Finland, is currently working on timing special events like the beginning and end of a satellite's passage. Richard Hines shoots for 40 targets per observing session. The most ambitious plan belongs to Jay Respler, who wants to record the apparent brightness of every possible object in orbit.

Once your materials are organized, don't forget to give your eyes time to dark adapt. Although you can walk out of a lighted house and see Mir, you can't do that for many others. Unless your site is light-polluted, you should be able to see naked-eye satellites to about 6th magnitude. Anything dimmer and you'll need a pair of 7x35mm (or 7x50mm) binoculars. Since you'll be holding these over your head, find a lightweight pair.

The "must have" equipment is a comfortable lounge chair, an accurate watch, a red light to read your charts by, and a current element set. If your elements or your watch aren't accurate, you're not going to find your satellite.

How many of your targets will you find? Richard Hines's best night was 23 out of 40. Don't be disappointed if you can't track down everything on your list. After all, some of these birds are small and flying high.

Tracking Sats on the Web

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Georgia State University Prediction Service
http://www.chara.gsu.edu/sat.html

Brian Webb's Rawhide Space Page (Brian Webb)
http://ourworld.compuserve.com/homepages/rawhide_home_page/ (Vandenberg Launches, how to photograph satellites)

NASA/GSFC Orbital Data Bulletin Board
http://oigsysop.atsc.allied.com/ (Elements)

U.S. Naval Observatory Master Clock
http://tycho.usno.navy.mil/what.html or phone 1-719-567-6742 (Accurate time signal to set your watch or your computer's internal clock)

Satellite Tracking Web Page
http://staff.feldberg.brandeis.edu:80/~progrmer/satellite/satellite.html (Excellent source of element files and satellite links)

NASA Spacelink
http://spacelink.msfc.nasa.gov/Instructional.Materials/Software/.index.html (Orbital and Tracking Elements)

Spacewarn Bulletin
http://nssdc.gsfc.nasa.gov:80/about/about_spacewarn.html (Up-to-date satellite announcements)

SKYSAT
http://members.aol.com/skysatrj/index.html (Elements)

NSSDC Master Catalogue Spacecraft Query Form
http://nssdc.gsfc.nasa.gov/nmc/sc-query.html

Obitessera Web Site
http://www.mindspring.com/~n2wwd/

For a more complete list including links to the sites listed above, visit *Astronomy* at: http://www.astronomy.com

The brilliant white slash of the Space Shuttle Columbia cuts across the skies of Havant in Hampshire, England. Vega is the bright star at top left on November 28, 1983.

H. J. P. Arnold

Once You're Hooked

"In for a penny, in for a pound?" If so, you might as well go all out and join the Internet mailing list for visual satellite observers called SeeSat-L. Here you'll find the wünderkinder of orbital mechanics. If you have a question about observing sats, this is the place to ask.

Along with posts on viewing techniques, unusual observations, and software announcements, the list has up-to-date elements for new satellites, spy birds, and other objects with frequent orbital changes (Mir and the Shuttle).

When I joined the list there was a lot of talk about predicting Iridium flares. Although the satellites themselves are fairly dim, sunlight reflecting off the antennae produces a sudden, brilliant flare which can be brighter than Venus and last as long as 20 seconds. IRIDFLAR and SKYSAT attempt to predict these events. The estimated magnitude of the flare is given, along with the exact longitude and latitude of the event maximum. The centerline may be a block from your house or several miles away. Better still, use this as an excuse to buy a GPS (Global Positioning System).

Something for Everyone

The night I first saw Atlantis docked with Mir, a friend who was with me asked, "Why do you watch satellites?" At the time the answer seemed so obvious I struggled to reply. But since then, I've pondered the question. I finally decided that my fascination with satellites was somewhat akin to my love of observing the moon. I remember telling a deep-sky buff what a thrill it was to watch sunrise unfold across a lunar crater. "Boooooring," he responded. To him, nothing could equal peering into the furthest recesses of the universe. He loved his views distant and untouched. But for me, satellites, like lunar footprints, tell the truest of tales. We were there.

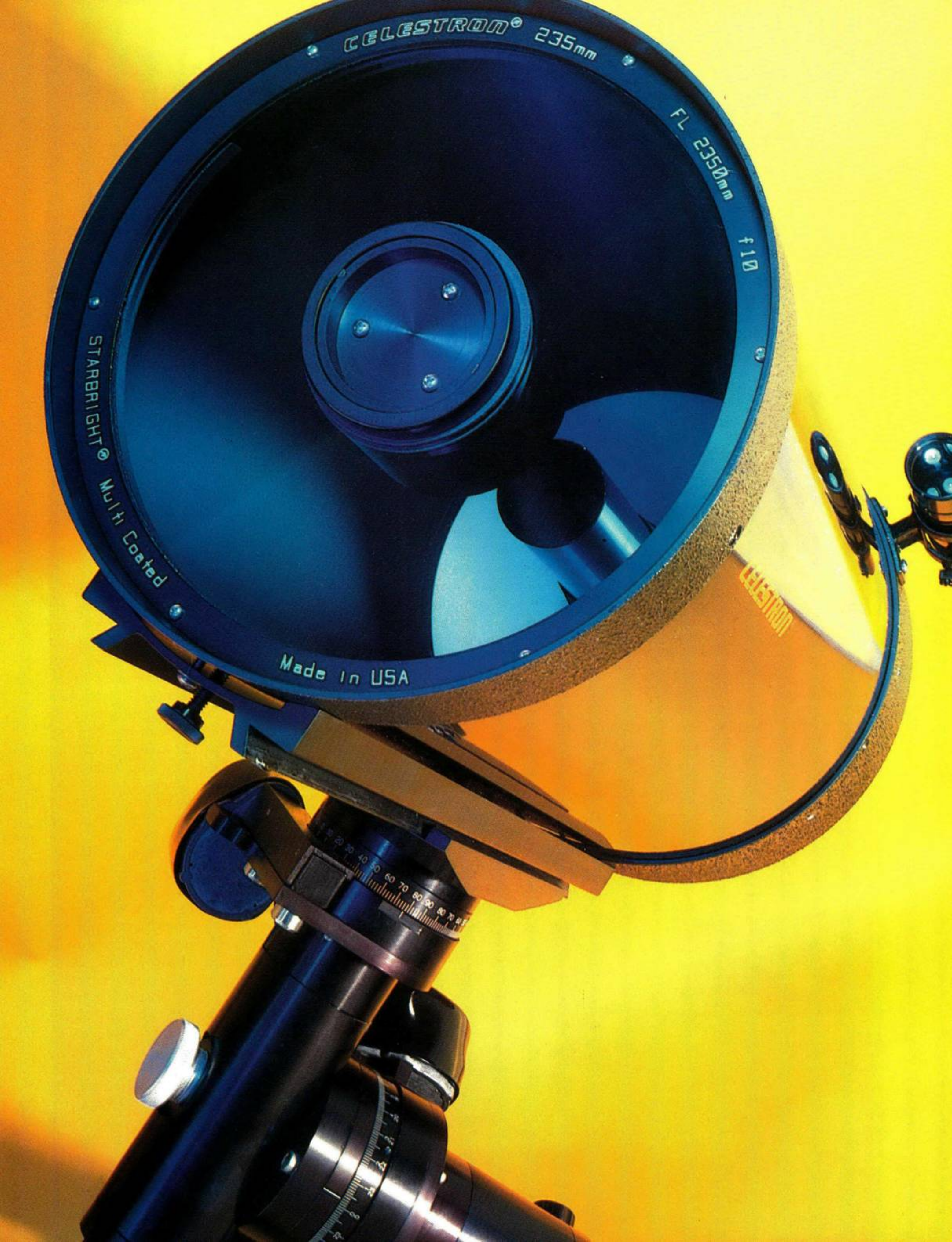
In 1973, when Tom Smith saw his first satellite, he savored the moment, believing it would never come again. Fortunately for Tom, and all of us, our nights are still filled with the chorus "There it is!" ■

Nancy Hendrickson is a freelance writer living in San Diego. When she's not chasing satellites, she's climbing her family tree. She co-authored, with David Cortner, Eight Easy Observing Projects for Amateur Astronomers. *She can be reached at: stjoemo@ibm.net.*

Strike a Pose

Celestron's 9 ¼-inch Schmidt-Cassegrain telescope drops the conventional fork mount and improves performance.

by John Shibley


CELESTRON® 235mm
FL 2350mm
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STARBRIGHT® Multi Coated
Made In USA
CELESTRON

The popular 8-inch Schmidt-Cassegrain telescope is the standard for moderate-aperture, "one-person" telescopes. It is amateur astronomy's workhorse. Now, Celestron has improved upon that design by adding to a more stable mount, smarter tracking, and a larger, 9¼-inch mirror. The result is Celestron's CG 9¼, a scope that has 34 percent more light-gathering power and weighs only 10 pounds more than the 8-inch SCT. While the CG is a bit more difficult to set up than the SCT you may have seen or used, I think the extra effort is worth it.

The core of the CG is its 9¼-inch diameter f/10 mirror. It bounces incoming light back up to a front-mounted secondary mirror, which reflects the light back through a hole in the main mirror to a focuser. The mirror may not look much different than an 8-inch, but it is deceptively stronger. So too, is what that slightly larger tube sits on — a German equatorial mount instead of a fork equatorial mount. The German design is best for deep-sky photography and sky-tracking because it offers balance to a much finer degree than does a fork mount. How? Imagine a person sitting in a chair and holding a telescope in both hands at arms' length — no matter how hard he tries to hold it steady, a small bump from your nose or a breeze can cause the scope to wobble. The German mount, in this analogy, would allow the telescope tube to rest, perfectly balanced, in his lap — small bumps and breezes hardly disturb it.

Both types of mounts can be equipped with tracking motors that align on a stationary point of sky in the Northern or Southern Hemisphere. There is no doubt that fork equatorial mounts offer value for the investment. But the fork mounts have more jiggles during long-exposure astrophotography, which can generate fuzzy photographs.

Fork mounts have some advantages. For instance, Celestron's 9¼-inch fork-mounted cousin, the Ultima, is easier to store, transport, and set up than the CG. And the CG's portable field tripod jiggles more than it should because it is not as sturdy as it should be. Tightening screws that hold the legs in place improved this only marginally, and the occasional vibrations continued. Because of this, I'd recommend that anyone planning to use the CG for long-exposure, deep-sky photography purchase Losmandy's beefier GM-8 field tripod for $400 extra. Save the lighter and more portable CG field tripod for general observing.

But the CG's weak tripod didn't overshadow its superior design.

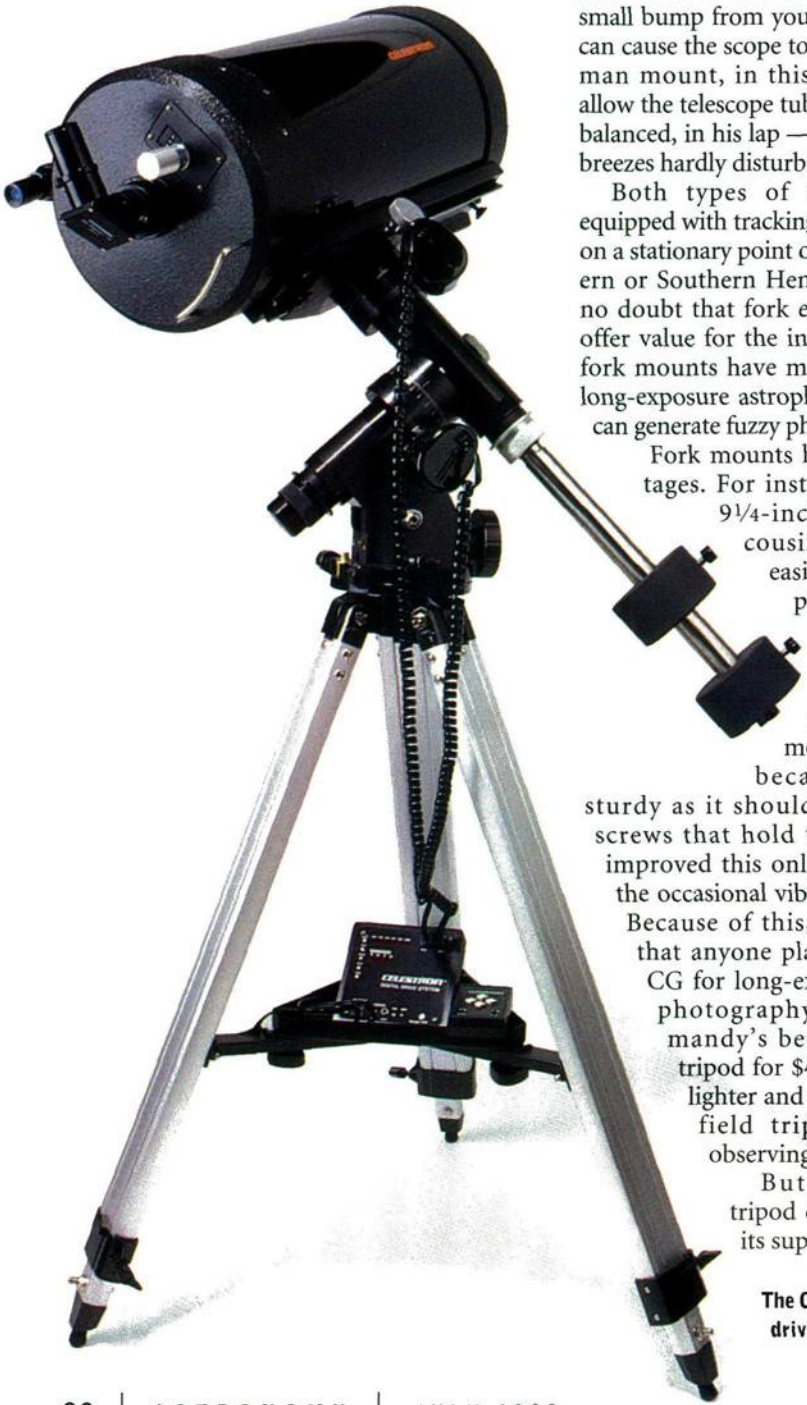
Every part of the telescope's head is made from machined aluminum or steel. All components in the unit I tested fit together snugly and moved smoothly when lock knobs were released. Where other mounts might use score pins to lock down the axes, the CG's head employs twist-lock sleeve clamps. Slightly loosening or tightening these clamps yields precise amounts of friction, in case you want to gently reposition the scope's aim. However, I found a lack of manual slow-motion controls made it difficult to precisely center objects in the eyepiece. For that, I used the scope's electric drive motors and hand controller.

Tripod Tweaks

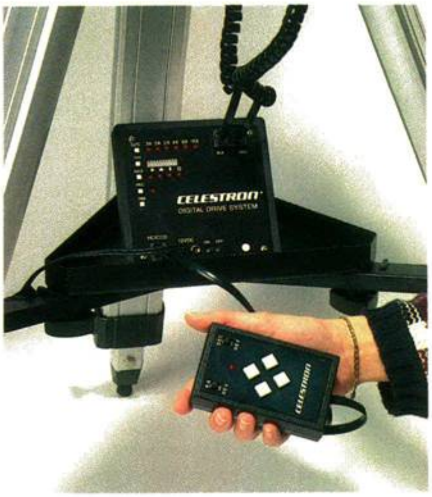
To get started, first level the tripod by adjusting its legs up or down. Built-in dual bubble levels aid greatly in ensuring the mount is level. Next, orient the mount toward the celestial pole by loosening the oversized, 5-inch knob and adjusting the declination axis between 0° and 64°, depending on your latitude. You can fine tune the mount on the celestial pole by loosening two wing-bolts at the base of the mount and swiveling the mount.

For those of you observing from the Northern Hemisphere, align the mount on celestial north, which lies near Polaris. Re-tighten the wing-bolts: Brass adjustment knobs let you turn the mount head in azimuth until the polar axis points due north. You can speed up polar alignment by purchasing Celestron's optional polar alignment scope. It slips into the polar axis, through a hole bored in the declination shaft. Celestron markets both a Northern Hemisphere and a Southern Hemisphere version. Long exposure astrophotographers might find the polar alignment scope useful, but for general observing and lunar photography, I found more conventional alignment methods worked just as well.

Balancing the telescope tube on its right ascension and declination axes is next. It is a vital adjustment and a breeze to perform. Why bother balancing? One reason is preventive: An out-of-balance telescope stack makes gears in the clock drive work harder and less efficiently. In the short term, a stressed drive doesn't do its job smoothly. Over the long haul, gears



The Celestron CG 9¼ makes tracking easy with a control box, two built-in drive motors, and a DC power line.



A hand-held controller allows observers to "teach" an error-correction feature to adjust for slight tracking errors in each observation.

Metal counterweights are positioned to precisely counterbalance the weight of the tube on the declination axis.

The telescope is balanced on its right-ascension axis by sliding the tube back and forth until it no longer teeters.

wear out and persistent tracking errors creep in. However, the primary reason is more immediate: A balanced telescope jiggles less and takes sharper photographs than an unbalanced one.

The field of view of an equatorial telescope will wobble slightly, even if it is perfectly balanced and there are no breezes or other disturbances, because of flaws in the motor drives' worm gears. These gears can cause vibrations even when they turn slowly. However, the performance of the CG's 2.8-inch, 180-tooth drive gear was virtually flawless, yielding an error less than 10 arcseconds. To compensate for variances even this tiny, the CG's electronic drive box includes a chip that "remembers" for eight minutes the corrections you make with the hand controller. This is about the time it takes the main worm gear to make one complete revolution. After such a "training" period, activate the periodic error correction (PEC) feature, which automatically makes the compensations. After training my controller, the mount's tracking error shrank to less than 3 arcseconds.

Delicately Balanced

To balance, loosen the telescope tube right ascension axis lock and slide the tube back and forth. Reposition the telescope tube several times; when it no longer teeters in either direction, tighten the knob. You're now half balanced. Balancing the declination axis uses a different procedure. Unlock the declination axis: A shaft with black, metal counterweights on one end and the tube assembly on the opposite end will move up or down. The point here is to simply slide the weights up or down until the shaft no longer tips in either direction. You're fully balanced.

Now it's ready to electronically track with the sky thanks to the control box, two built-in drive motors, and a power line that plugs into a vehicle cigarette lighter. This design reflects a philosophy that places the CG under remote, star-splashed skies, where the only source of power comes from a car. Urban astronomers, not to mention lunar and planetary observers who don't need inky dark skies, can power the scope through AC adapters readily available through any astronomical equipment dealer.

The two tracking motors will move at independent rates. Our sun and moon move slightly slower than the sky, hence the controller has solar, lunar, and sidereal tracking rates for stars. A "king" rate factors in an optical-refraction effect that comes from viewing targets less than 20° above the horizon.

These primary drive rates are supplemented by slew rates of 0.3, 0.5, 2, 4, 8, and 16 times the sidereal rate. Hold the right ascension drive correction button down for two seconds at the 16x setting, and the right ascension drive jumps to 32x. A separate motor slews the declination axis. These slew features made "cruising" the moon's sunrise terminator during field tests a feast for the eyes.

In the CG 9¼, Celestron offers a portable telescope that mates the compact pedigree of Schmidt-Cassegrains with the functional precision of a German equatorial head, along with fantastic drive electronics to boot. ▣

John Shibley is a contributing editor for Astronomy *magazine.*

CG-9¼ STANDARD SPECIFICATIONS

Aperture: 9.25 inches (235mm)
Focal ratio: f/10
Focal length: 2,350mm
Secondary Mirror Obstruction: 36% (by diameter)
Length of tube: 21.625 inches
Size of focuser: 1.25 inches.
Included 1.25-inch eyepiece: 26mm (Plössl, 90x)
Photographic field: 0.59° by 0.88°
Weight of tube: 25 pounds
Weight of mount and tripod (without counterweights)**:** 35 pounds
Warranty: one year, materials and workmanship
Typical retail price: $2,995

(Includes 6x30mm finder, drive electronics box, hand controller, vibration suppression pads, adjustable aluminum field tripod, 26mm Plössl eyepiece, 1.25-inch star diagonal, 15-foot cigarette-lighter socket power cord)

Celestron International, 2835 Columbia Street, Torrance, CA 90503; phone, (310) 328-9560; fax, (310) 212-5835.

See our website for more product reviews at http://www.astronomy.com

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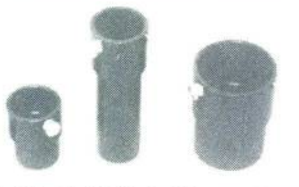
LOTS OF ADAPTERS



2" adapter for C-8, Meade 2080, etc. .. **$29.50**
2" adapter for C-80, C-100 refractor ... **$39.50**
2" adapter for C-70, C-80F, C-100F fluorite **$39.50**
2" adapter for C-6, Comet Catcher, Meade 312 **$30.00**

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2½" long extension (holds 1¼" filters) . **19.50**
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2"/T-thread adapter, threaded 48mm* .. **$25.00**
T-thread/1¼" adapter **$25.00**
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Low profile star diagonal eyepiece holder **$16.00**
Meade 2" Diagonal/Giant Easy-Guider **$39.50**
**Threaded to hold 48mm filters.*

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LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. Uses 2 AA cells (incl.) which last 60-100 hours.

LUMILITE red LED flashlight **$14.95**
STARLITE™ adj. red LED flashlight **$24.95**

RICH FIELD! 2° in 8'' SCT

NOW ONLY
$99.95

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2" or 1¼" eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer **$99.95**
Giant Rich-Field Viewer (10-14") .. **$250.00**

Optional Eyepiece	**TRUE FIELD**	**Price**
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2" Wide-Field†	1.9°	**add $429**
Meade 40mm 2" Wide-Field†	2.4°	**add $489**

†Includes 2" enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

PENTAX 65° XL EYEPIECES

AMAZING performance! **All have** 20mm eye relief, adjustable helical eye guard, super multicoatings, **E.D. glass**.

5.2mm F.L., 65° Apparent Field 1¼" **$279**
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10.5mm F.L., 65° Apparent Field 1¼" **$269**
14mm F.L., 65° Apparent Field 1¼" **$269**
21mm F.L., 65° Apparent Field 1¼" **$269**
28mm F.L., 55° Apparent Field 1¼" **$259**
40mm F.L., 65° Apparent Field 2" .. **$299**

MEADE 7'' - 16'' LX200
NEW! 7'' - 10'' LX50

16'' LX200 $14,950

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller.
LX200 - full computer control w/64K obj. mem.
Tripod: extra for LX50; included for LX200
NOTE: A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200.

NEW! 3.5'' f/14 ETX Maksutov ($20) **$595**
ETX, showroom price *(no 8 month wait)* **$649**
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Field Tripod for 8" LX10 ($20 P&S) .. **$195**
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Wedge for photographing w/8" LX200 **$139**
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10'' LX50, f/10 w/wedge, dec. motor, hand controller ($155 P&S) **$1695**
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12'' LX200 (f/10 only)($215 P&S) **$4495**
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8'' f/6
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New 8'' f/6 Meade Starfinder telescopes

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*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

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Includes Computer, Encoders, Hardware

LOW PRICE—from $299

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
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- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

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Over 3600 objects! — Also includes planets and full visual descriptions.

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NGC SKY VECTOR with IDENTIFY (Sky Tour) mode, 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16" Dobsonian.
Ultima 8, 9¼, 11 **add $25**, C-14 **add $75**

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Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

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New! Thread-on for Odyssey

FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape!
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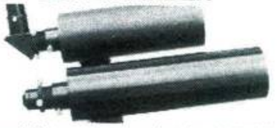

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1¼" O.D. plug, seals focuser ...... **4/$2**

2" O.D. plug	**2/$2**	3½" O.D. plug	**$1.50**
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1½"	**2/$2**	9½", 10.4"*	**$15**
2"	**2/$2**	12½", 12⅞"* ...	**$20**
2⅛"	**2/$20**	15.0", 15.6", 16"*	**$28**
5½"	**$6**	19" (DS-16)	**$35**
*Fits Odyssey		21" (Odyssey-II)	**$35**

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ALWAYS GET THE BEST VIEW!

$99
(If ordered with LUMICON filter or filter set)

The New LUMICON Multiple Filter Selector holds up to 5 1¼" LUMICON filters. The sliding bar has a click-stop at each filter position. Now you can instantly select the best filter for any deep-sky object. Cost is $129 or $185 with 1.5X relay lens (for Newtonians). **Save $30 if ordered with filter(s)!**

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Ranger 70mm f/6.8 apochromat w/45° diag.	**$659**
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32mm Plossl, widest true field in 1¼"	**$125**
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2" Paracorr Visual Coma Corrector	**$259**
15mm Panoptic 1¼", 68° field	**$215**
19mm Panoptic 1¼", 68° field	**$245**
22mm Panoptic 1¼"/2", 68°	**$285**
27mm Panoptic 2", 68° field	**$335**
35mm Panoptic 2", 68° field	**$365**

TeleVue Warranty may not be valid outside USA.

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1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
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LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." ***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

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SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

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*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

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1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$199.50**
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2" Rear Cell Filter, fits SCT's Deep-Sky, **$199.50** UHC, O-III, H-Beta,	**$199.50**
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48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Choice of ***any two*** LUMICON filters (**Save 7%**) 1¼" **$185.00**; 48mm	**$370.00**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼" $99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50; 48mm**	**$199.50**
LUMICON Comet (Swan band) Filter **1¼" $99.50; 48mm**	**$199.50**
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Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$19.50**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$25.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

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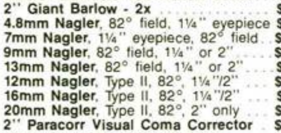

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
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Specify telescope size: 6", 8", 10", 11", 14", 16"

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52, 55, 58, 62mm	**$69.00**	**$199.50**
67, 72, 77mm	**$79.00**	**$399.50**
82mm (77mm + adapter)	**$89.00**	**$415.00**

Hypered 2415 film, 36 exp **$11.95, $3/$32**

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†U.S. Patent 4,473,636

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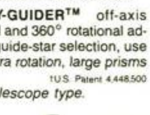
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
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Pentax 6X7 **add $129;** Pentax 645 **add $149**

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Pentax 6X7 **add $129;** Pentax 645 **add $149**

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Adapter for Hasselblad **$399,** Mamiya 645**$149**
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2. **Cable release** for long exposures . **$9.95**
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6. **LUMICON 48mm DEEP-SKY FILTER $199.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

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Scotch
1000
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2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Gold 1000 fast, fine grain	12	**$13.95**
Fuji G800 fine grain color neg.	**24**	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$8.50**

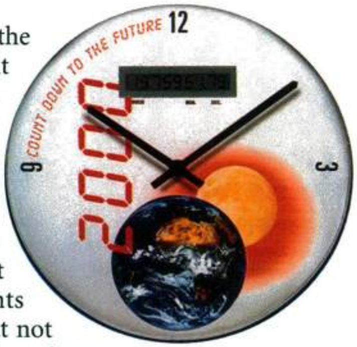
A PRODUCTS

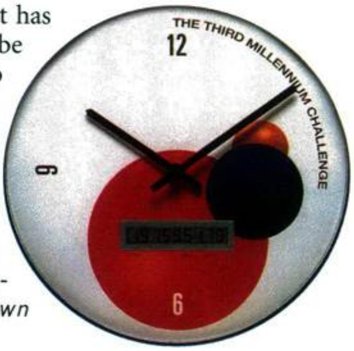
"From the Earth to the Moon" Telescope Line

▶ Tasco, one of the world's largest distributors of quality sport optics, has signed an exclusive liscensing agreement with HBO for the network's "From the Earth to the Moon" miniseries — an agreement that will result in the creation of an official optic product line to accompany the television programming. The miniseries, a sequence of 12 episodes dramatizing the stories of the Apollo missions, premiered on April 5, 1998; it grew out of a landmark partnership between Tom Hanks, Imagine Entertainment (the team that created the movie hit *Apollo 13*), and HBO. As part of the liscensing agreement, Tasco will develop a new optic product line — including one microscope and four telescopes — intended for novice to intermediate astronomy enthusiasts. Merchants are encouraged to contact their local Tasco sales representative to order their own "From the Earth to the Moon" telescopes today.

Tasco, P.O. Box 269000, Pembroke Pines, FL 33026; phone, (954) 252-3600; customer service, (888) GET TASCO; fax, (954) 252-3705; website: http://www.tascosales.com.

CountDown Wall Clock





▶ We are hurtling toward the year 2000, and as the days diminish, the excitement grows. Extravagant parties to celebrate the arrival of the third millenium are being planned on land, air, and sea as never before. Some will spend the evening lavishing on cruise ships or jetting across time zones in the Concorde for the longest New Year's Eve party ever. But for most of us (who will celebrate New Year's Eve 1999 in our living rooms and not the Rainbow Room) Braco International presents the *CountDown wall clock* — a zany timepiece that not only keeps regular time but also displays a digital read-out of the hours, minutes, and seconds until the year 2000. But have no fear, when the much anticipated moment has come and gone, your *CountDown clock* can still be put to work — it can easily be set to count down to any other target date like a birthday, anniversary, wedding, graduation, retirement, or due date. The *CountDown clock* is available in two different styles, each depicting the sun, Earth, and moon as symbols of time.

Branco, 91 Main Street, Kings Park, NY 11754; phone, (800) 528-7445, (516) 544-4606; fax, (516) 544-4145; e-mail, branco2000@hotmail.com. *CountDown wall clock*: $69.95 plus shipping and handling.

Zenit 122M Astrophotography Kit

▶ Are you an astrophotographer plagued by dead camera batteries? With the majority of cameras on the market today, power is drained from the battery every time the shutter opens, and more power is required for longer exposures. The *Zenit 122M* may be just the solution you've been seeking. The *Zenit 122M* is all manual and only uses a battery for the metering system, which isn't necessary in astrophotography anyway. Included in the package is a 1.25-inch camera adapter — letting you take photos either at the telescope's prime focus or with eyepiece projection using 1.25-inch eyepieces. A cable release completes the kit to lock and hold the shutter open. The cable also serves to reduce camera and telescope wobble.

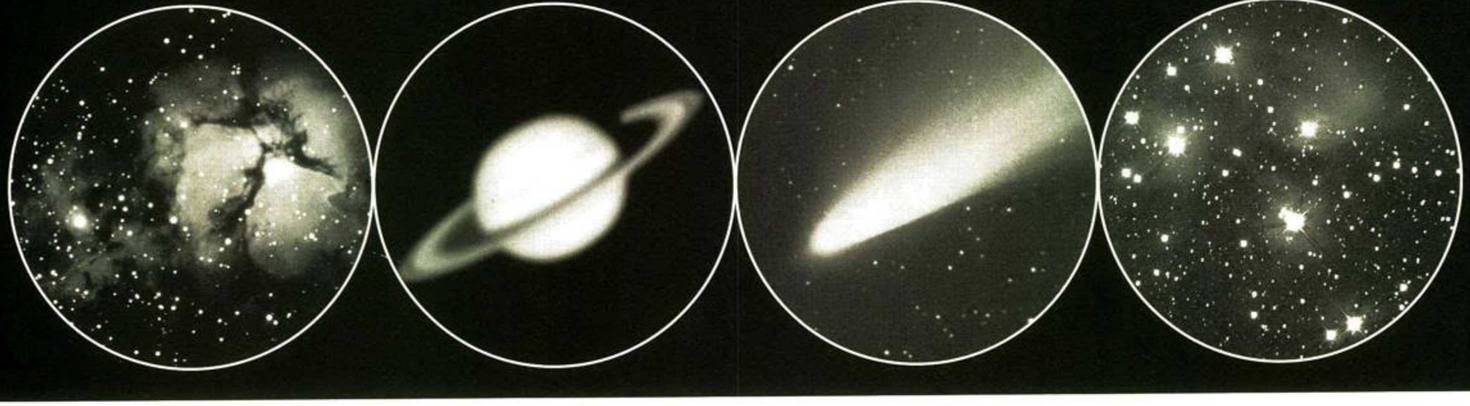
The Widescreeen Centres, 48 Dorset Street, London, England, W1H 3FH; phone, 0171-935 2580; fax, 0171-486 1272; e-mail, call@wscreen.demon.co.uk; website, http://www.wscreen.demon.co.uk. *Zenit 122m Astrophotgraphy Kit*: $165.

Swarovski Optik Astronomical Eyepieces

Four new astronomical eyepieces in 30x, 77x, 115x, and variable power (20–60x) are now available from Swarovski Optik. Designed to fit most telescopes, each eyepiece has a 1.25-inch mounting barrel tube, and the 20–60x variable eyepiece is considered by many to be one of the finest variable astronomical eyepieces available to both amateur and professional astronomers. Swarovski Optik is also introducing an adapter ring that will allow the new eyepieces to fit their full line of scopes.

Swarovski Optik, One Wholesale Way, Cranston, *RI 02920*; phone, *(800)* 436-3089, (401) 942-3380; fax, (401) 946-2587; website, http://www.swarovskioptik.com. 30x, 77x, and 115x eyepieces: $265.55; Variable power eyepiece: $343.33.

We can show you what's out there... But we'd rather you see for yourself.



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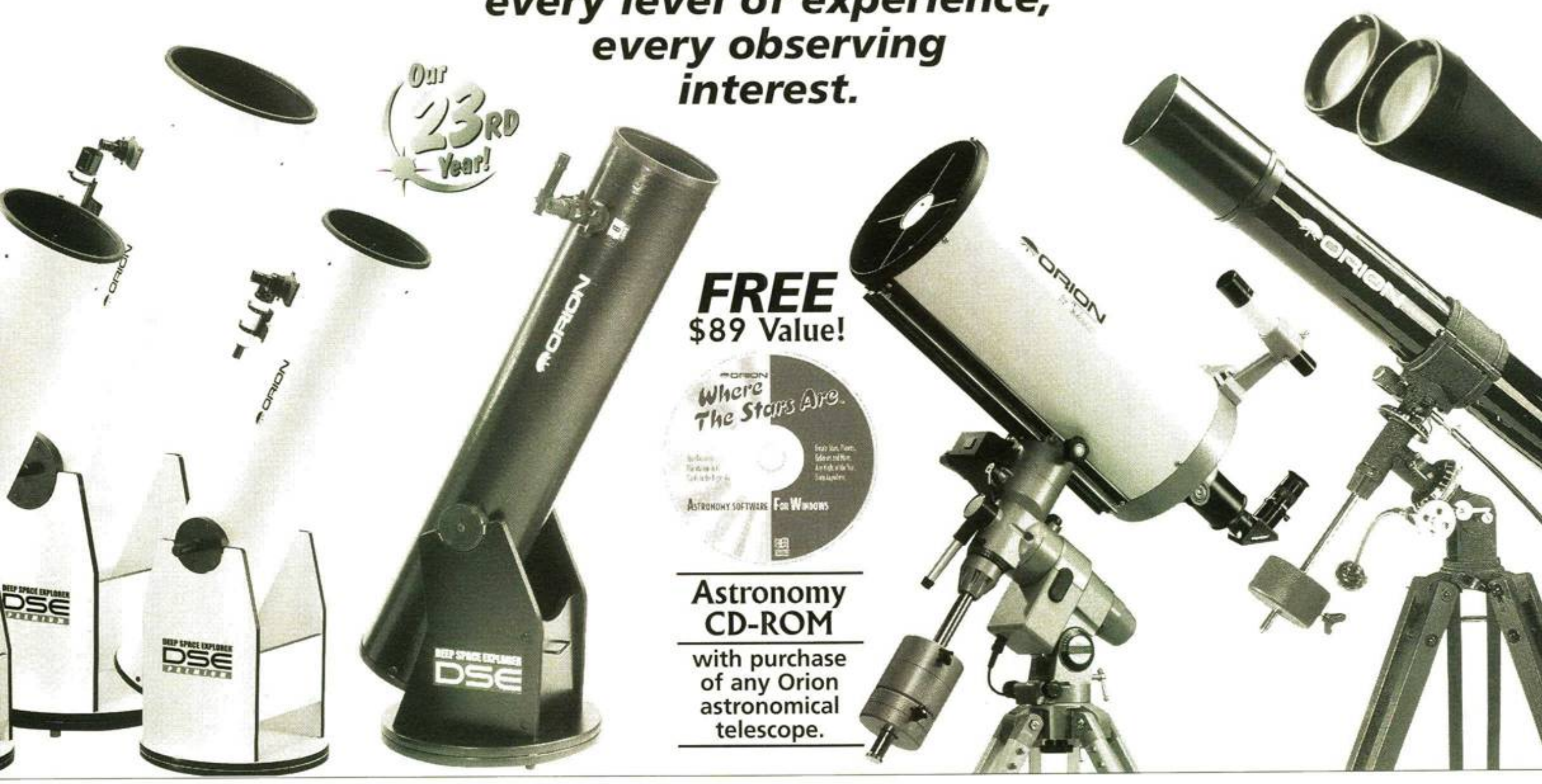

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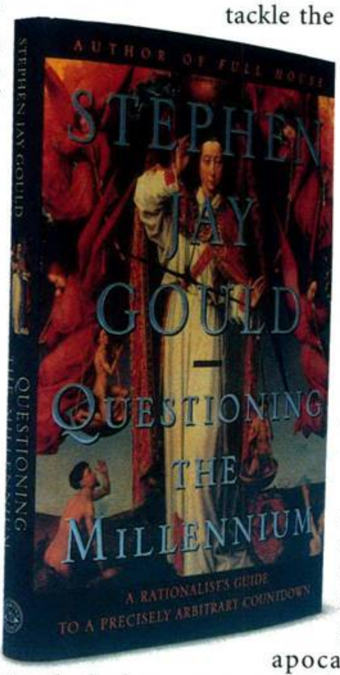
BOOKS

Questioning the Millennium: A Rationalist's Guide to a Precisely Arbitrary Countdown

Steven Jay Gould, 190 pages, Harmony Books, New York, 1997; ISBN 0-609-60076-1; hardcover, $17.95.

▶ *Questioning the Millennium*, by Stephen Jay Gould, is a sure bet for anyone who has ever bought one of those illuminating books that explains why a four minute egg takes three minutes to cook on the moon — or is it the other way around? With the facade of a hardback, an impressive cover, the peppering of Western apocalyptic art among its pages, and the even more impressive knowledge of exactly who Professor Gould is, you'll hardly know you hold in your hands another brick in the encyclopedic masonry of "Why Things Are The Way They Are."


AUTHOR OF FULL HOUSE
STEPHEN JAY GOULD
QUESTIONING THE MILLENNIUM
A RATIONALIST'S GUIDE TO A PRECISELY ARBITRARY COUNTDOWN
STEPHEN JAY GOULD
QUESTIONING

Fortunately for the reader and for Gould, the Harvard scientist and evolutionary theorist has avoided all major pitfalls of this often bland genre and delivered an entertaining account. Most importantly, he has picked a fascinating, timely topic: the issue of the millennium and the three major questions that surround it. One, what is the millennium (other than simply a thousand-year period) and its connection to apocalyptic Christianity, i.e. Christ's predicted future thousand-year reign on earth? Two, when does the next millennium begin, 2000 or 2001? And three, why is there such an interest in the millennium — and in transitions?

The answers are surprisingly far-reaching and engaging, and Gould weaves them into a generally pleasing, personal narrative, without sacrificing either accuracy or thoroughness. What the millennium is and how it relates to such varied issues as lunations, the Book of Revelations, the Wounded Knee Massacre and other seemingly disparate topics makes for an inherently good story. As the story unfolds, Gould clears away all potential roadblocks in a highly readable manner, by explaining any calendrical and other difficulties. If only he could find a way to overcome the greatest single barrier that all books in this genre face: making us remember the explanations more than two minutes after we put the book down. Perhaps all a writer can hope for in penning a book of this sort is that the reader understands as he reads.

To tell the tale right, Gould must tackle the whole problem of calendrics and the various arbitrary attempts to track uncooperative rotations and revolutions of the Earth, and lunations, all of which don't divide evenly into one another and cause a whole host of difficulties. He also gives a competent overview of apocalyptic origins and subsequent history, highlighting relevant social patterns when they present themselves.

The first, or "what," section nicely sets the stage for us, explains much of the relevant astrocalendrical issues, gives a nice overview of apocalyptic or "millennial" movements (as many of them came to be called), and details the historical connection between these issues and their resulting movements.

The "when" section is just as fascinating. Most of us know the basic reason for the dispute between 2000 and 2001 as deriving from the absence of the year 0, but the full story contains much, much more, particularly the implications that this absence has had for Christian apocalypticism through the years. Gould is quite adept at handling such an array of information. For the most part, he heeds the caveats he laid down for himself at the beginning and sticks to his three questions, letting the story tell itself and only clarifying and fleshing out when need be.

"Why" is that most problematic of words. Fortunately, though, "why" can take on many different shades of meaning. For example, the question "Why did Pope Gregory initiate calendrical reform in 1582?" is a tame, straightforward one, and the last section delightfully clears up (momentarily at least) issues of this sort. Why are lunar calendars the way they are? Why has Easter come to be?

His analyses of humankind's penchant for order — manifested by, among other things, an aesthetic desire for nice round numbers ending in zeros — and of other relevant psychological tendencies are strong, and some would cite this third section as proof of why we should have read the book in the first place.

The question of the millennium and all of its "cascading implications" is a highly personal one for Gould, and the final epilogue in which he shares his experiences with an acclaimed autistic day-date calculator (i.e., you tell me any date, I'll tell you the day it fell on) is a genuinely touching finale. In the end, the breadth and depth of Gould's story in *Questioning the Millennium* makes us glad that he tackled the daunting job that writing about this subject presents. — *Ryan E. Moore*

Millenium Star Atlas

Roger W. Sinnot and Michael Perryman, 1,548 pages, Sky Publishing, Cambridge, Massachusetts, 1997; ISBN 0-933346-84-0; hardcover, $249.95.

Roger W. Sinnot and Michael A. C. Perryman have worked for more than 2½ years to produce the *Millenium Star Atlas*, a comprehensive new map of the heavens brought to you by Sky Publishing and the European Space Agency (ESA). With the largest chart scale (100 arcseconds per millimeter) and faintest limiting magnitude (V=11) of any all-sky atlas now in print, the *Millenium Star Atlas* works hard to distinguish itself from those that came before — and succeeds. More importantly, perhaps, is the first-ever use of new data from ESA's *Hipparcos and Tycho Catalogues*, which give precise positions, brightnesses, distances, and proper motion for more than 1,058,000 stars measured by the Hipparcos satellite from 1989 through 1993. And coauthor Sinnott has carefully chosen the more than 10,000 star clusters, bright and dark nebulae, and galaxies depicted in the atlas.

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— *Jeanette Brown*

BYTES

Astronomical Images

▶ Images of 29 well-known deep-sky objects taken with the professional 40-inch Jacobus Kapteyn Telescope at the Roque de los Muchachos Observatory (Canary Islands, Spain) will be yours with *Astronomical Images*, a new CD-ROM from Twin Press. But more than simply beautiful images, this software offers students, teachers, astronomers, and amateurs a realistic, professional set of CCD exposures to reduce to qualitative, calibrated images that can then be used in the analysis of scientific information. The CD-ROM contains raw, multicolor 1124x1124 CCD exposures in two-byte integer FITS format and all the necessary calibration files. The program is ideal for teaching purposes because it allows the teacher to focus on teaching rather than on searching for suitable material and the appropriate calibration files — everything a teacher needs will be at his or her fingertips.

Each color of the objects has two frames to illustrate the effect of cosmic rays on CCD images. Additionally, all necessary auxiliary frames have been added for all colors and objects. Finally, a short introduction to the techniques of CCD reduction gives students a good idea of how and why certain techniques can and must be used, which will save valuable time once the student is actually at the telescope.

Twin Press Astronomy Publishers, Oosterkamp 9, 8381 BV Vledder, The Netherlands; phone, 31 521 38 38 11; fax, 31 521 38 36 10; e-mail, g.kiers@twinpress.nl; website, http://www.twinpress.nl. Price: $39. Minimum requirements: DOS; Windows 3.X, 95, or NT; UNIX/Linux; or Mac O/S; image reduction or analysis software that can handle FITS images; CD-ROM drive.

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The Windows-based program on this disk has the additional features of allowing users to add up to 50 of their own images and/or sounds as well as automatic password protection (selected and engaged at the user's discretion) to lock entry to one's computer when the screen saver is activated. While you are away from your desk, private files are secure and company business is safe from inquisitive eyes.

Nature Scenes Software, RR #2, Olds, Alberta, Canada T4H 1P3; phone/fax, (403) 556-7356; e-mail, mjfarms@telusplanet.net. Price: $14.95. Minimum requirements: Windows 3.1 or Windows 95, 256 color monitor, 3.5 MN hard drive space, 600 kB RAM, sound card optional but required to hear sounds.

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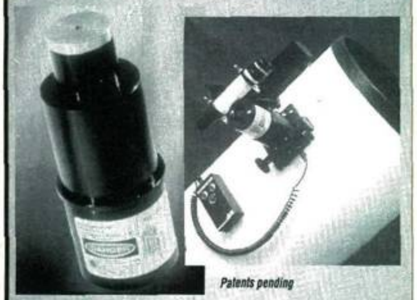

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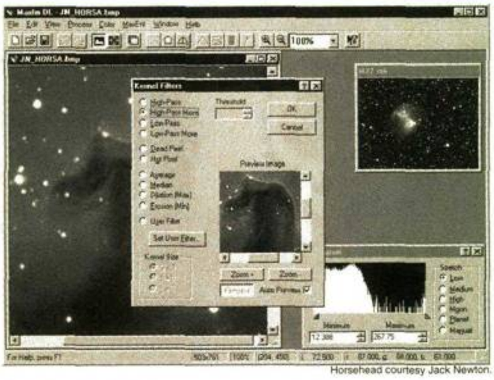

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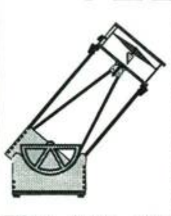

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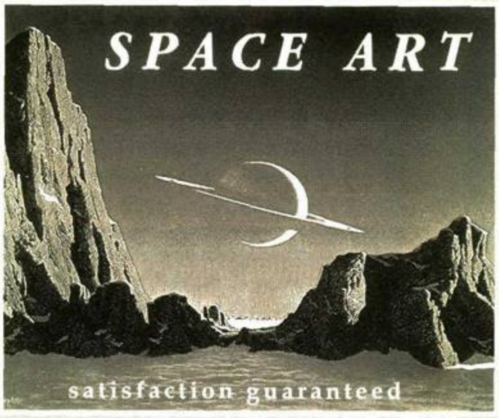

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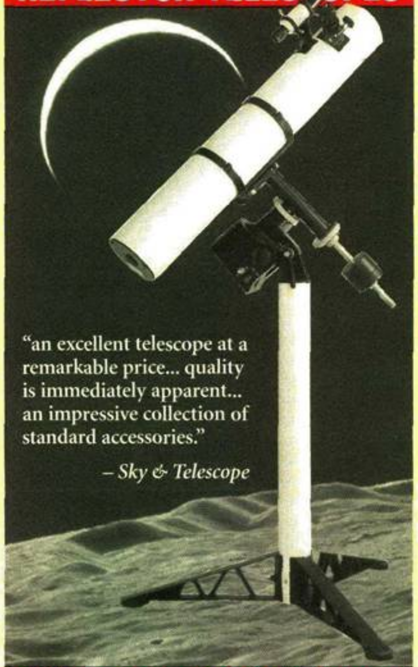

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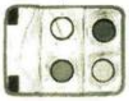

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The **Nebraska Star Party, July 18-25**, has gained a reputation as one of the premier star parties in the country due to the extremely dark skies and many daytime recreational opportunities in the area. Attendance has quadrupled over the last four years; NSP '98 is expected to draw 400 amateur astronomers from across the nation.

Observe from the highest point between Ontario and the Rockies at the **Saskatchewan Summer Star Party, July 23-26**, in Cypress Hills Provincial Park, Saskatchewan, Canada. Wildlife abound — moose wander the area — but there are no large predators and few mosquitoes. Stargazers travel from as far as Arizona to enjoy outstanding seeing in this unique natural setting.

JUNE-SEPTEMBER

Summer Public Observing

▶ Naperville Astronomical Association's Observatory, Springbrook Water Reclamation Center, Naperville, Illinois. Wednesdays, 7:30 p.m. Call if the skies are questionable. Contact George Simon, Jr., (708) 983-5029; or Drew Carhart, (630) 978-1133.

JULY 1

Hurricane Ridge Star Party

▶ Olympic National Park, Port Angeles, Washington. Hosted by the National Park Service and Port Angeles High School Astronomy Club. Contact John Gallagher, (360) 452-0260 (day) or (360) 452-7764 (eve.); e-mail, jgalla@orca.esd114.wednet.edu.

JULY 9-11

ALPO '98 — Association of Lunar and Planetary Observers Convention

▶ Fernbank Museum of Natural History, Atlanta, Georgia. Contact Ken Poshedly, (770) 979-9842 e-mail, ken.poshedly@mindspring.com.

JULY 11

Free Public Star Party

▶ Ralph A. Worley Observatory, south of Shreveport, Louisiana. Sponsored by the Shreveport-Bossier Astronomical Society. Contact Cran Lucas, (318) 797-1524, or visit the society's website at http://www.lsus.edu/nonprofit/sbas/.

John E. Cordiale

Stellafane summer night. The Stellafane Convention is July 24-25 in Springfield, Vermont.

JULY 12-14

Annual Convention of the Society of Amateur Radio Astronomers

▶ NRAO, Green Bank, West Virginia. For information contact Vince Caracci, (516) 798-8459; e-mail, vinhell@juno.com. For registration, call Hal Braschwitz, (216) 252-8177; e-mail, W8PN@stratos.net.

JULY 17-18

Free Public Observing Event

▶ Lemon Lake County Park, near Cedar Lake, Indiana. Sponsored by the Calumet Astronomical Society. Contact Nick Zivanovic, (219) 931-8790; e-mail, info@casonline.org; website, http://www.casonline.org.

JULY 17-18

Mid-States Regional Convention of the Astronomical League

▶ Harvey and Bernice Jones Center for Families, Springdale, Arkansas. Contact Eliot Neel, 2300 Old Wire Road, Fayetteville, AR 72703; (501) 443-9127; e-mail, eneel@ad.com.

JULY 17-19

Telescope Making Contest

▶ Parc des Iles de St-Timothee, near Montreal, Quebec, Canada. Contact (514) 377-2493; e-mail, ypregent@rocler.qc.ca.

JULY 17-26

Summer Star Party

▶ Shady Pines Campground, Savoy, Massachusetts. Sponsored by the Rockland Astronomy Club. Contact Don Urban, 73 Haring Street, Closter, NJ 07624; (201) 768-6575; e-mail, DonaldUrban@Juno.com.

JULY 18-25

Nebraska Star Party

▶ Merritt Reservoir, near Valentine, Nebraska. Sponsored by the Prairie Astronomy Club and the Omaha Astronomical Society. Contact Tom Miller, 3400 N. 102nd Street, Lincoln, NE 68527; (402) 466-4170; e-mail, tmiller232@aol.com; website, http://www.4w.com/nsp/.

JULY 19

Space Day

▶ Adler Planetarium, Chicago, Illinois. Contact (312) 322-0304; 24-Hour Information Line, (312) 922-STAR; website, http://astro.uchicago.edu/adler/.

JULY 21-25

ALCON – Annual Convention of the Astronomical League

▶ French Lick Springs Resort, French Lick, Indiana. Hosted by the Evansville and Louisville Astronomical Societies. Contact Charles Miller, Registrar

ALCON '98, P. O. Box 3474, Evansville, IN 47733; e-mail, CHMiller13@aol. com; website, http://ourworld.Compuserve. Com/homepages/sconner.

JULY 23-25

Saskatchewan Summer Star Party

▶ Cypress Hills Interprovincial Park, Saskatchewan, Canada. Contact SSSP '98, Saskatoon Centre, RASC, P. O. Box 317, RPO University, Saskatoon, SK S7N 4J8; e-mail, dickson@sk.sympatico.ca or keser@ duke.usask.ca; website, http://maya. usask.ca/~rasc/rasc.html.

JULY 23-25

Table Mountain Star Party

▶ Ellensburg, Washington. Sponsored by the Northwest Region of the Astronomical League, P. O. Box 785, Puyallup, WA 89371; e-mail, tmsp @triax.com; website, http://www. tmspa.com.

JULY 24-25

Stellafane Convention

▶ Breezy Hill, Springfield, Vermont. Sponsored by the Springfield Telescope Makers. Contact Stellafane Convention, P. O. Box 50, Belmont, MA 02178; e-mail, tom@solar.njit.edu; website, http://www.stellafane.com.

JULY 24-26

Gateway to the Universe

▶ Powassan, Ontario, Canada. Hosted by the North Bay Astronomy Club. Contact Merlin Clayton, 50 Van Horne Crescent, North Bay, ON, P1A 3L3; Tom Ouellette, (705)474-7666; website, http://www.efni.com/ ~brentt/nbclub/nbclub.htm.

JULY 24-26

Island Star Party

▶ Wright's Farm, Vancouver Island, British Columbia, Canada. Contact Frank Ogonoski, 1482 Kingsview Road, Duncan, BC, V9L 5P1; phone/fax, (250) 748-5110; e-mail, cvstarcl@cvnet.net; website, http://starfinders.cvnet.net.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or to tconley@astronomy.com. Look for additional events at http:// www.astronomy.com.

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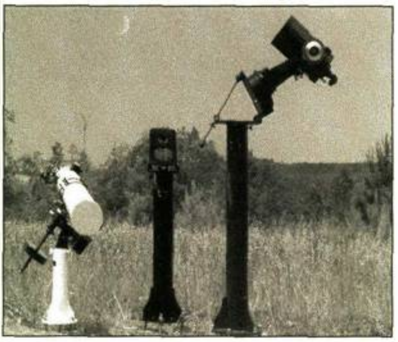

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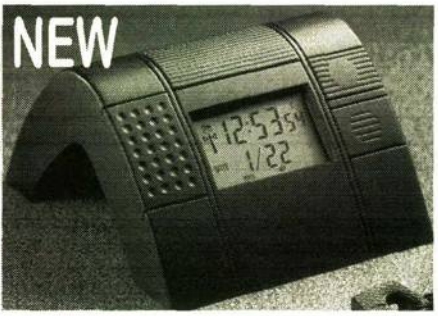

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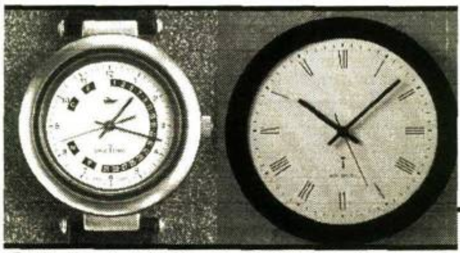

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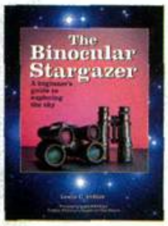
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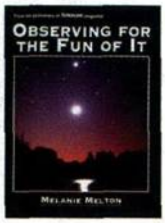
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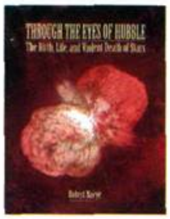
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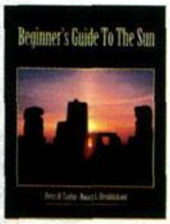
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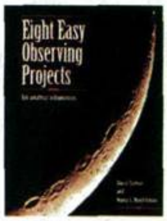
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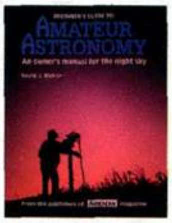
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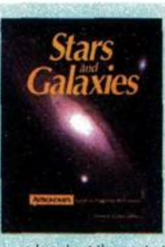
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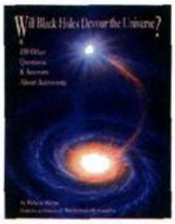
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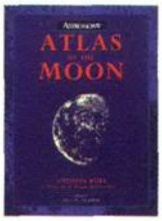
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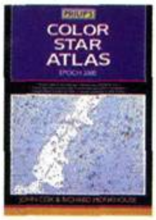
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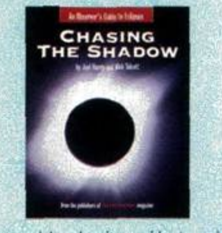
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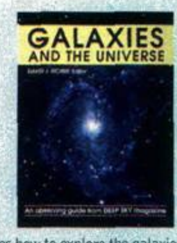
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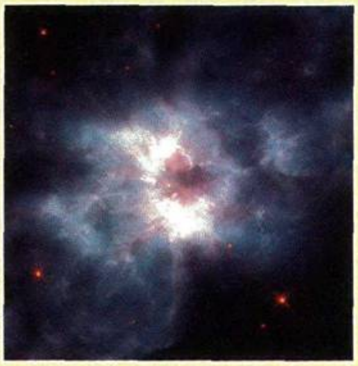
AD INDEX

ASM Products ... 108
Adirondack Video Astronomy ... 109
Adorama ... 112, 113, 127
Analytical Scientific ... 115, 127
Arcron Zeit ... 117
Astro-Physics ... 23, 108
Astronomics ... 81
Astronomy Shoppe ... 114, 127
Astrosystems, Inc. ... 108
Ball Photo Supply ... 115
Beigle/Bryant Engineering ... 110
Bergen County Camera ... 127
Berger Brothers Camera Exchange ... 114
Bethany Sciences ... 110
Blue Sky Pages ... 114, 115
CBH Travel ... 106
CC Sales/Camera Corner, Inc. ... 127
California Telescope Co. ... 106
Camera Bug ... 114, 127
Captain's Nautical Supplies ... 127
Michael I. Casper Meteorites ... 107
Celestron International ... 64, 65, 66, 67
Cruise Holidays ... 111
Cyanogen Productions ... 107
Day Star ... 33
Dover Photo Supply ... 127
Eagle Optics ... 115, 127
Edmund Scientific Company ... 17
EfstonScience, Inc. ... 115
FC Meichsner Company ... 117, 127
Farrier Software ... 108
Focus Camera ... 78, 79
Fujinon ... 19
Giselle's Travel ... 107
Innovations in Travel ... 110
Internet Telescope Exchange ... 108
Into the Wind/The Kite Source ... 109
JMB Inc ... 18
Jack Schmidling Productions, Inc. ... 109
Jim Kendrick Studios ... 33
Jim's Mobile Industries ... 21, 29
Kalmbach Publishing Company ... 18, 21, 32,
... 80, 105, 118, 119
Keys Pulse Motion ... 107
Khan Scope Centre ... 115
Knollwood Books ... 110
Krollkraft ... 107
Labenne Meteorites ... 111
Lasermax, Inc. ... 106
Lesueur Manufacturing Co. ... 117
Lumicon ... 98, 99, 127
Marketplace Pages ... 106, 107, 108, 109, 110, 111
Mars Society ... 19
Mayhugh Travel ... 21
Meade Dealer Pages ... 14, 15
Meade Instruments Corp ... 2, 3, 7, 8, 9,
... 10, 11, 12, 13, 130
Millenium Marketing ... 107
Minerva Press ... 110
Mountain Skies Astronomical Society ... 108
Murnaghan Instruments ... 33
Neptune Photo ... 115
New Mexico Astronomical ... 114
Newport Glass Works ... 110
Nisur Systems ... 110
Novagraphics ... 109
Nurnberg Scientific ... 115
Oceanside Photo & Telescope ... 27, 114, 127
Orion Telescopes & Binoculars ... 101
Oughten House Publications ... 21
Piranha Interactive Publishing ... 25
Pocono Mountain Optics ... 38, 39, 127
Psignologic Services ... 110
QSP Optical Technology, Inc. ... 109
Radio City ... 111
Rainbow Symphony ... 106
Rex's Astrostuff ... 106
Rivers Camera Shop ... 20, 127
Samy's Camera ... 88
Santa Barbara Instrument Group ... 31
Sarasota - Division of Wolf Camera ... 114
Science Connection, Inc. ... 111
Scope City ... 27, 127
SETIQuest ... 111
Shutan Camera & Video ... 89
SITA World Travel ... 109
Sky Optics ... 115
Software Systems Company ... 23
Sovietski Military Connection ... 111
Star Hill Inn ... 107
Starsplitter Telescopes ... 108, 111
Stellar Vision ... 114, 127
Surplus Shack ... 110
TNT Binocular Mounts & Beyond Ltd ... 111
Tech 2000 ... 110
Technical Innovations ... 19
Tele Vue Dealer Page ... 127
Tele Vue Optics, Inc ... 128, 129
Telescope & Binocular Center ... 36, 37
Thousand Oaks Optical ... 23
Travel Quest ... 107
Travel Wizard ... 109
Tropical Adventures ... 111
Roger W. Tuthill, Inc. ... 27, 88, 111
University Optics, Inc. ... 20
Vernonscope ... 106, 109
Virgo Astronomics ... 109
What in the World ... 18
Wholesale Optics ... 103
Willmann-Bell, Inc. ... 107

NEXT month in Astronomy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ECLIPSE FINALE

Moon Shadow

From ship and shore, eclipse tales still pour in.

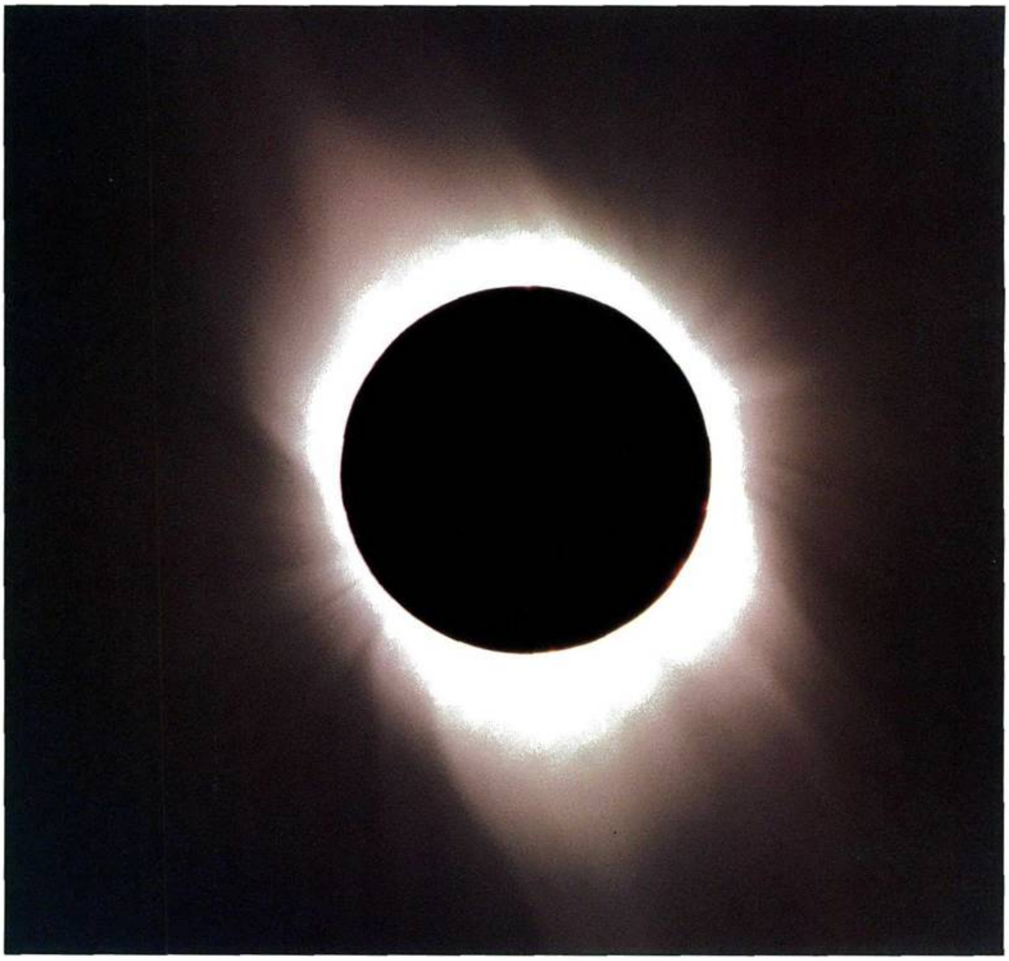
As the ship *ms Statendam* maneuvered to a position off the leeward side of Curaçao on the morning of February 26, 1998, the excitement on board began to intensify. Many had waited years to experience a total solar eclipse. A long-time friend and I were here to combine the delight of a Caribbean cruise with the century's last total solar eclipse in the Western Hemisphere.

The day dawned bright and clear, but soon the sky clouded completely, darkening the mood of the passengers as well as the scenery. By mid-morning, however, the clouds began breaking up. We hurried topside after breakfast to stake out a prime viewing location, racing the hoards of other territorial beings trying to establish their own unencumbered viewing space.

With solar filters in place, we began photographing the sun's intact disk. Meanwhile, the clouds gave way to sun, promising a fabulous show.

During the long partial phase of the eclipse process we conserved our film and watched people arrive on deck to observe the gradually changing sunlight.

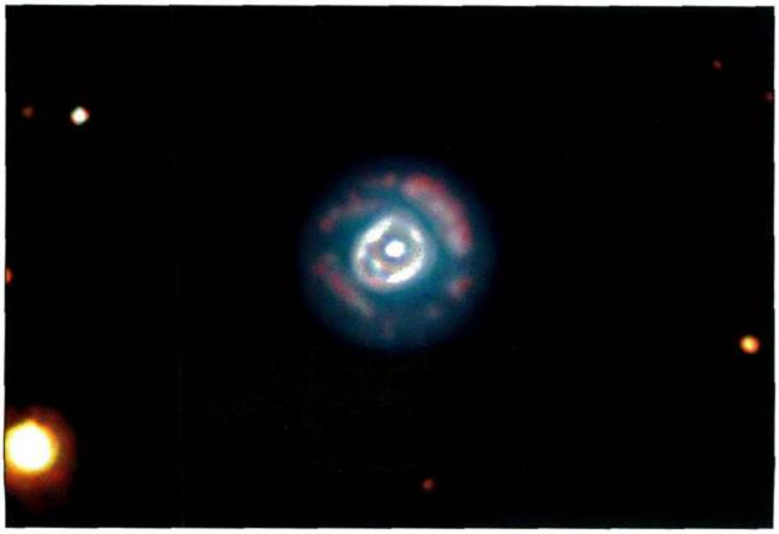
And what a change it was! As more of the sun's disk became covered, the sky took on a mysterious slate-blue hue and the surrounding colors began to look odd indeed. The sunlight intensity continued to drop as though the sun were setting or a gradually thickening layer of high clouds were forming. But shadows were still sharp,



Totality

DAN SCHECHTER

(4-inch f/5.8 refractor, Kodak Royal Gold 100 film, ¼-second exposure taken February 26, 1998, from Aruba)



The Eskimo Nebula (NGC 2392)

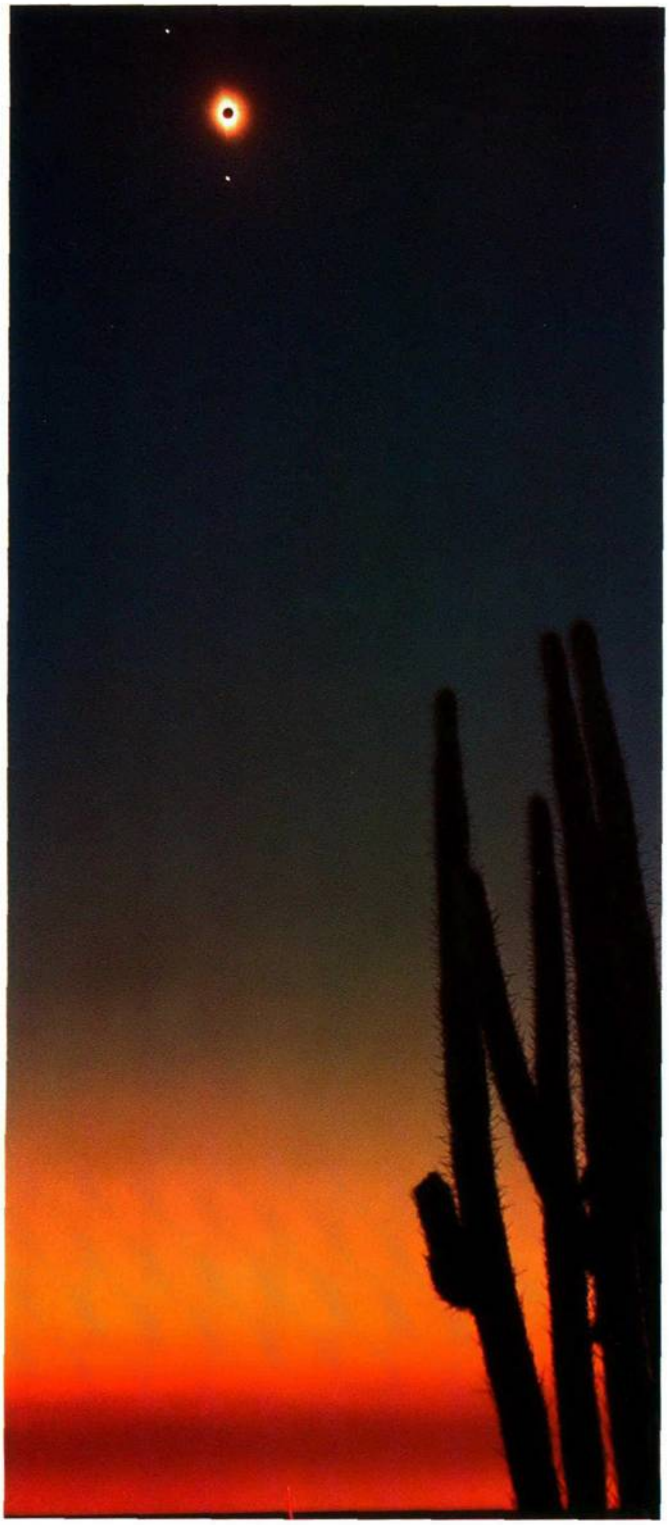
JACK NEWTON

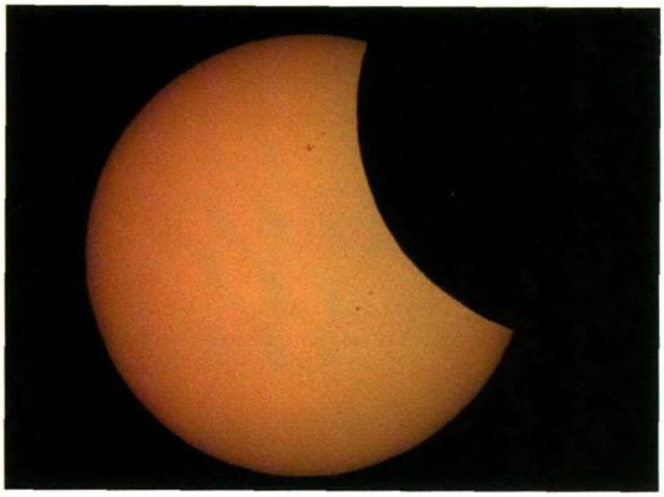
(16-inch f/6.3 SCT, Pictor 1616XT CCD camera, composite of 5-minute red, 20-minute green, and 40-minute blue exposures)

Mercury, Jupiter, and the Eclipsed Sun

JOHN POST

(90mm lens at f/16 on a Fuji 617 Panorama camera, Agfa 50 film, 4-second exposure taken February 26, 1998, at Peninsula de Paraguana, Venezuela)





Sunspots Eclipsed

ALBERTO AROSEMENA

(8-inch f/10 SCT, Kodak Gold 400 film, 1/500-second exposure taken February 26, 1998)

Eclipse Man in Venezuela

RICH SCARPITTA

(17mm lens at f/16, Fuji Velvia 50 film, 30-second exposure taken February 26, 1998) giving the environment a strangely mysterious and unfamiliar appearance.

At about 2 p.m., with most of the sun covered, the pace accelerated markedly. We noticed a dramatic decrease in ambient light, but shadows remained sharply defined. The deck filled quickly and the raucous din of routine life on board a cruise ship came to a halt as we became mesmerized by the grandeur of this event.

A few minutes before the onset of totality, there appeared on the western horizon a truly overwhelming sight. It looked like the biggest, blackest thunderstorm imaginable but without clouds, lightning, rain, or wind. Earth's demise appeared certain, and we could only watch, totally awestruck. It was the moon's shadow coming toward us at more than a thousand miles an hour; I anticipated its arrival anxiously.

The deck of the ship was now crowded with gasping and cheering spectators. With totality only 30 seconds away, the ship became awash in shadow bands caused by atmospheric disturbances brought to life by the small sliver of sunlight that remained — not unlike watching from underwater, but much more subtle.

We were now five seconds from totality, and as I pulled the solar filter off the camera lens, the last glimmers of sunlight, called Baily's Beads, became visible between the mountains on the moon's surface. After a second or two only a single bead remained, giving the appearance of a giant celestial diamond ring as the sun's atmosphere, the corona, became visible.

The entire sequence of events up to this point cannot even compare to the

The Veil Nebula

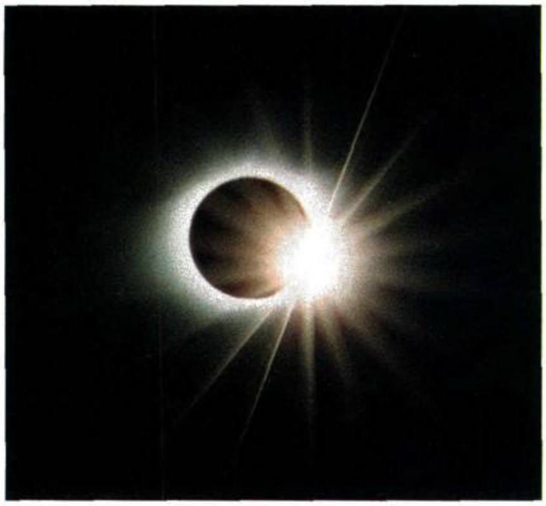
JERRY LODRIGUSS

(500mm lens at f/4, hypered Kodak PJM-2 film, composite of two 30-minute exposures)

A Diamond Ring That Dazzles

FRANKLIN J. FLOCKS

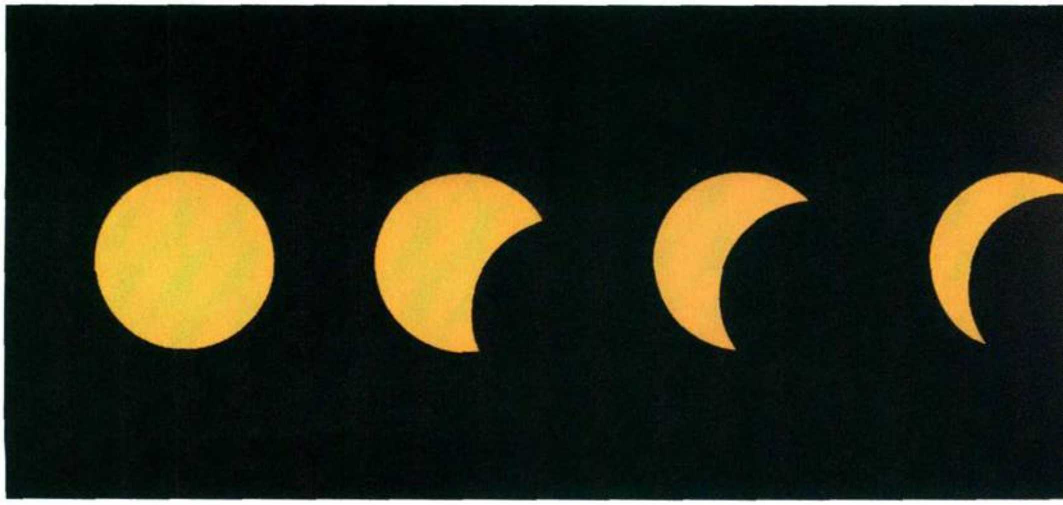
(200mm lens at f/11, Kodak Gold Max 800 film, 1/1000-second exposure taken February 26, 1998)



The Whole Solar Shebang

DAVID HANON

(Partial phases: 420mm lens at f/16, Kodak Gold 100 film, 1/250-second exposures; Totality: 420mm lens at f/4, Kodak Gold PPF 400 film, 1/30-second exposure, taken on February 26, 1998, just off the coast of Curaçao, Venezuela)

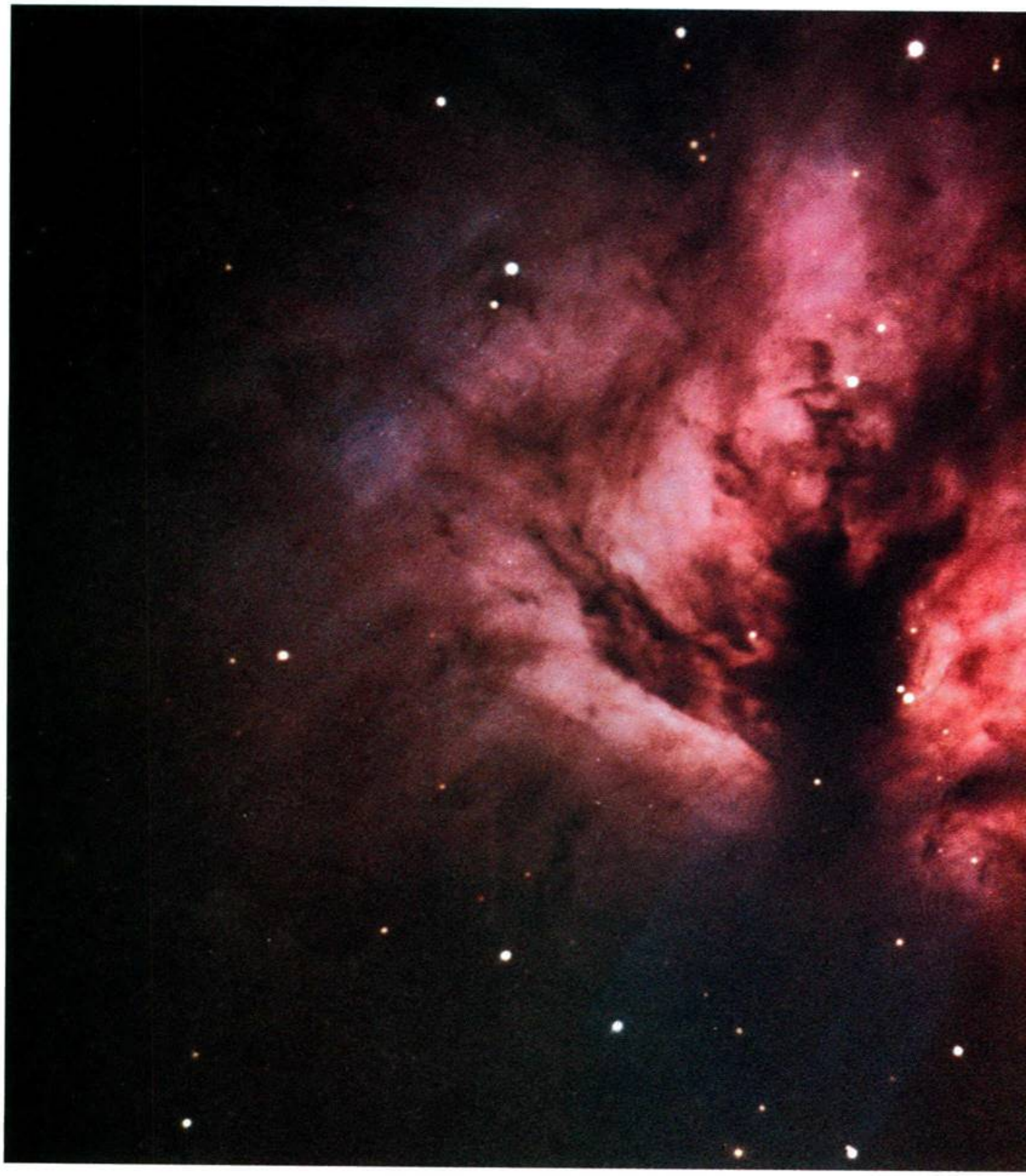


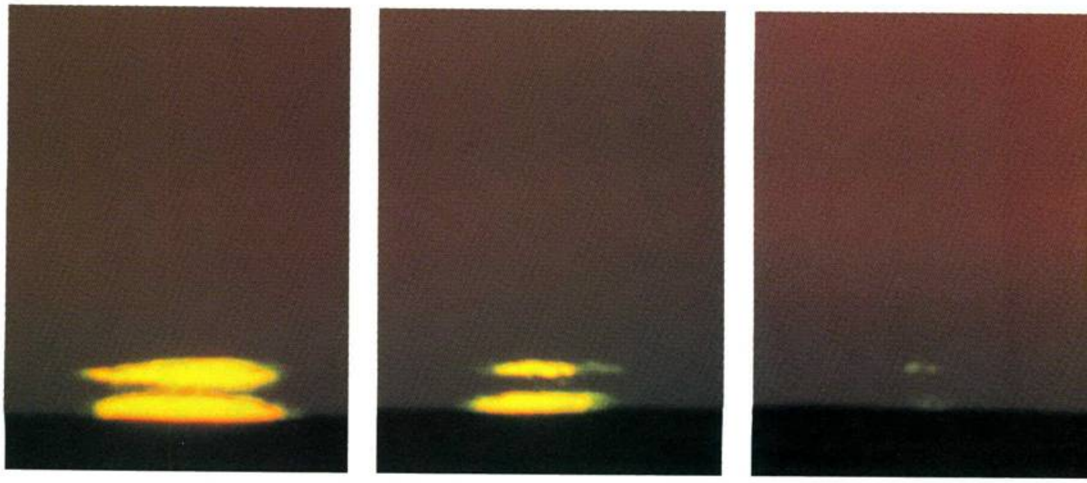
experience of totality. Solar prominences, immense red towers that could easily swallow Earth, leapt from the surface of the sun. The corona, blossoming in silvery magnificence, was textured by the sun's magnetic field, producing willowy strands that curved hundreds of thousands of miles away from the solar surface. All five of the major planets, Mercury, Jupiter, Venus, Mars, and Saturn, could be seen along with several of the brighter stars.

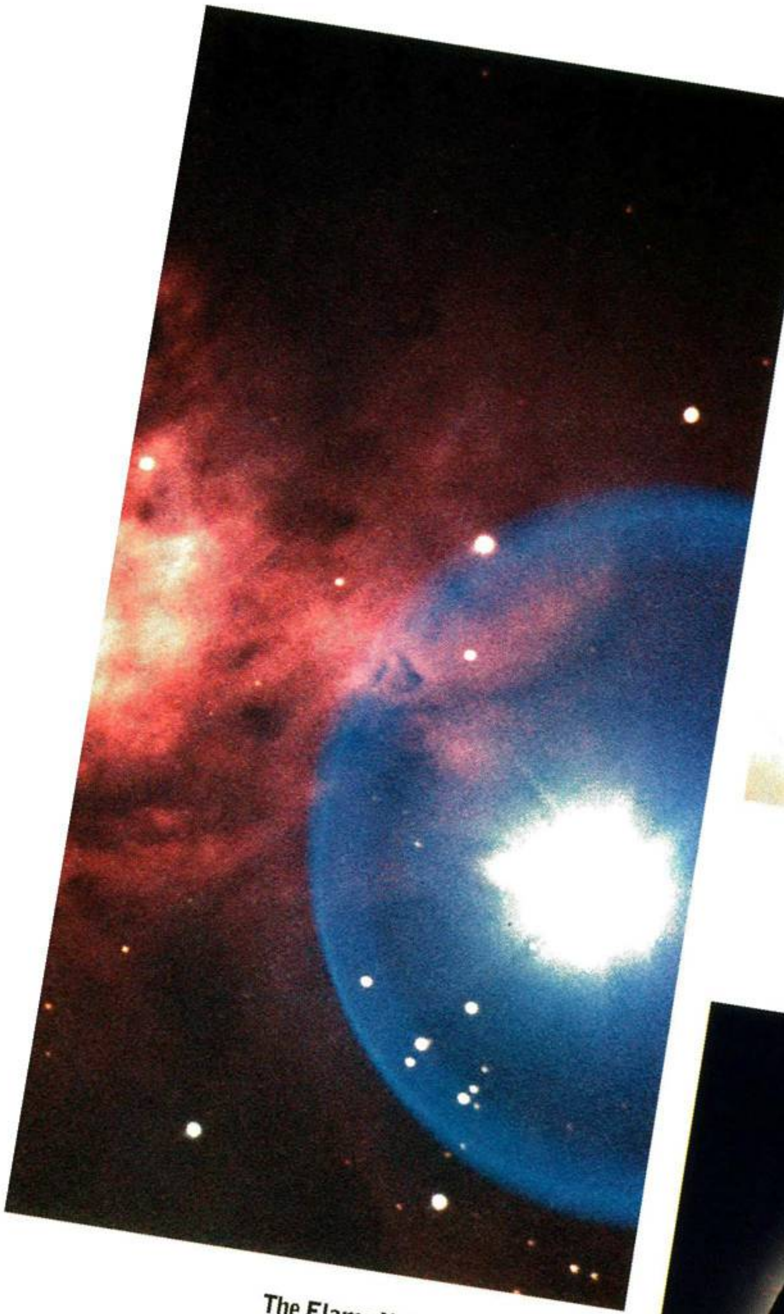
It was dark, as dark as a night illuminated only by a full moon. But it was a darkness unlike any other. We were surrounded by purple sky at the horizon, a hue that was rapidly evolving as the moon's shadow raced eastward. After just three minutes the western sky brightened significantly, and we knew that the awesome event of totality was about to conclude. As the moon's shadow moved past our location, eerie daylight once again enveloped us. The diamond ring effect and Baily's Beads were followed by shadow bands lasting a few seconds in the rapidly increasing brightness. With the disappearance of the shadow bands our surroundings began to look more and more normal as the sun slowly regained its usual appearance.

Before long, even while sunlight was still subdued and the moon's influence was very much with us, people packed up their equipment and began wandering back into the ship's interior. The experience of a lifetime had come to an end.

Robert K. Morrow is an eclipse chaser who calls Centerville, Indiana, home.







The Flame Nebula (NGC 2024)

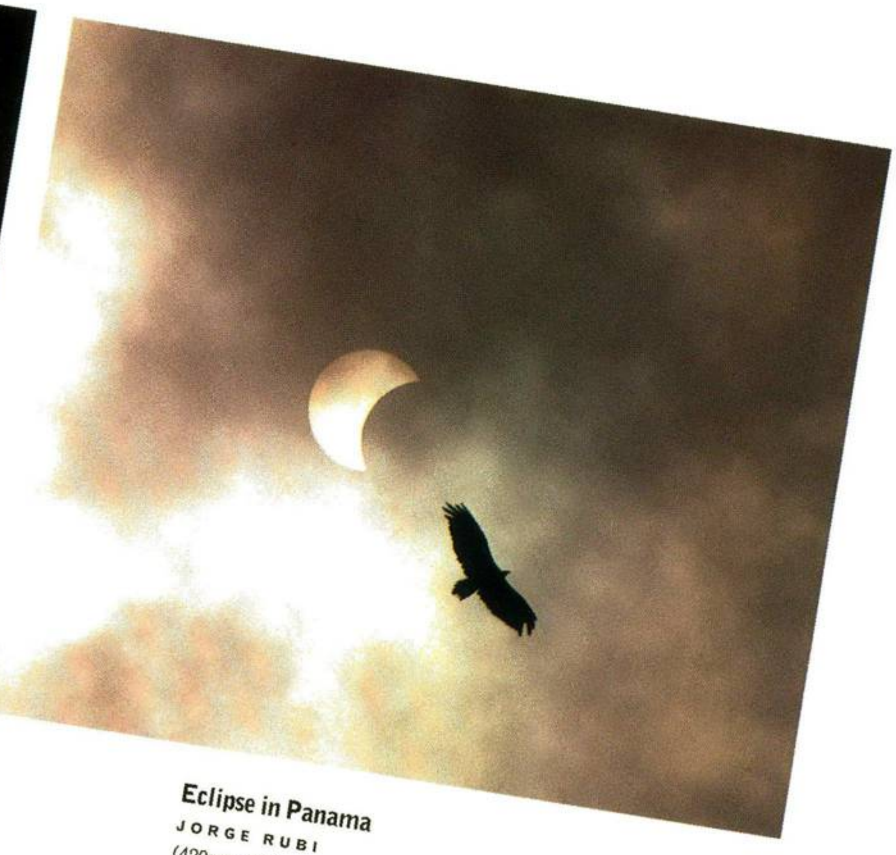
JASON WARE

(16-inch f/10 SCT, Fuji HG 400 film, composite of two 16-minute exposures)

A Green Flash Sequence

GIANNI TUMINO AND MELANIA PLUCHINOTTA

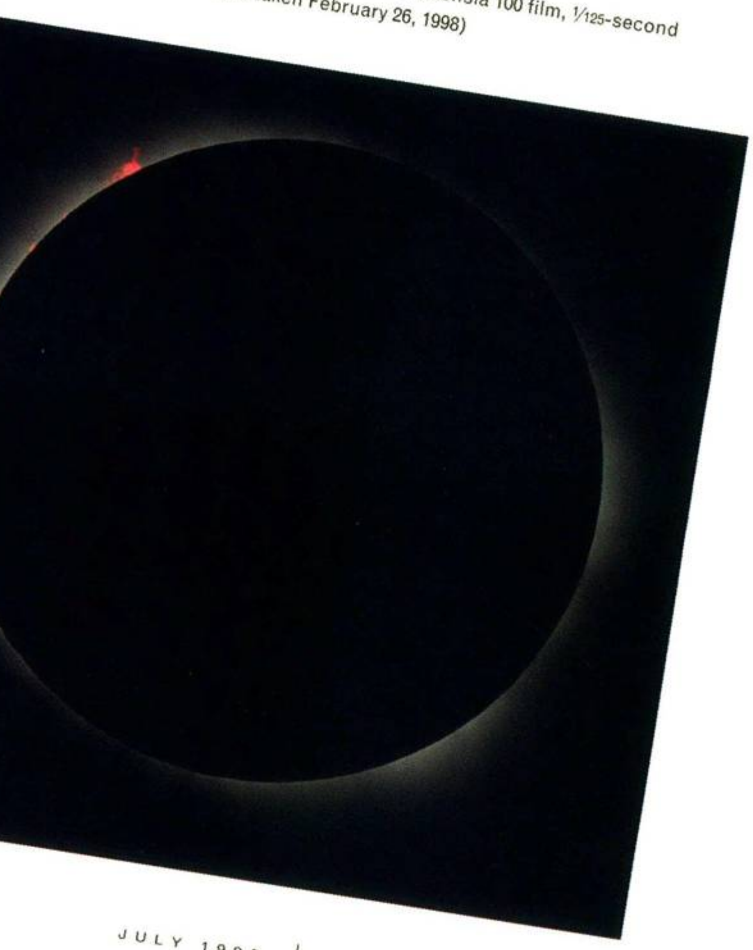
(10-inch f/10 SCT, Kodak Elite II 100, three 1/125-second exposures)



Eclipse in Panama

JORGE RUBI

(420mm f/7 lens, Fujichrome Sensia 100 film, 1/125-second exposure taken February 26, 1998)



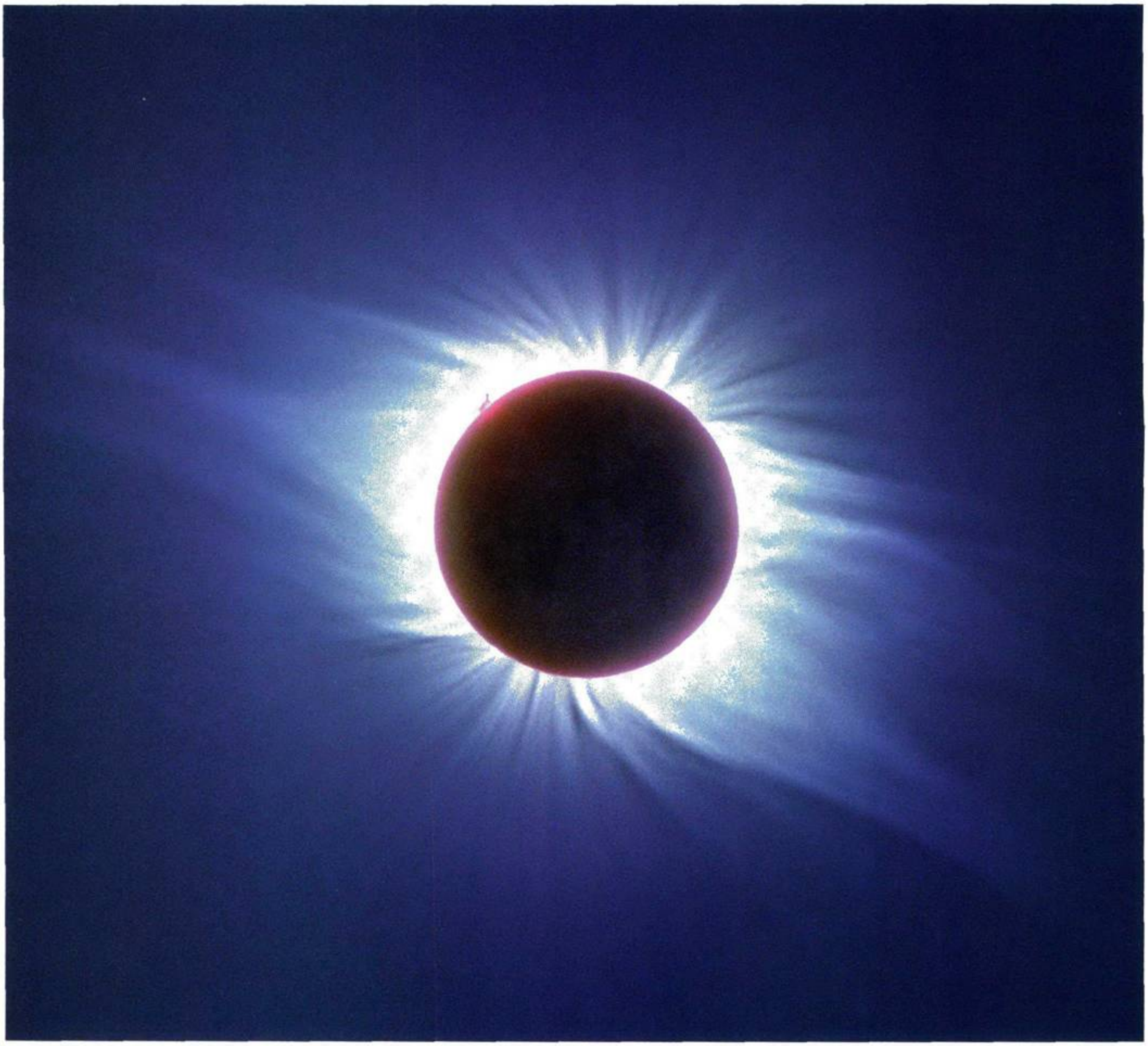
Prominent Prominences

JOHN A. VOLK

(4-inch f/6 refractor at f/14, Kodak Royal Gold 100 film, 1/250-second exposure taken February 26, 1998, from Curaçao, Venezuela)

ULTIMATE EXPOSURE

This month's best astrophoto



Illuminating the Shadow

FRED ESPENAK

The solar corona exhibits an extreme range in brightness that cannot be captured in a single exposure. Short exposures show the bright inner corona and prominences, while long exposures reveal faint details in equatorial streamers and polar brushes. Even longer exposures can reveal the "darkened" moon illuminated by Earthshine. Fred Espenak used a computer to combine a series of images taken at different exposures into a single composite image.

(80mm f/8 refractor, Kodak Royal Gold 100 film; Corona: composite of six shots — 1/125-, 1/60-, 1/15-, 1/8-, 1/4-, and 2-second exposures; Moon: composite of three shots — 1-, 2-, and 4-second exposures at f/8. All images taken February 26, 1998, from Oranjestad, Aruba)

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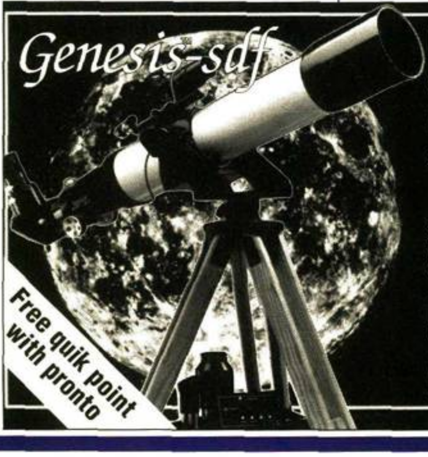

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Photo of Horsehead Nebula taken with Pronto by Ralph Sieger

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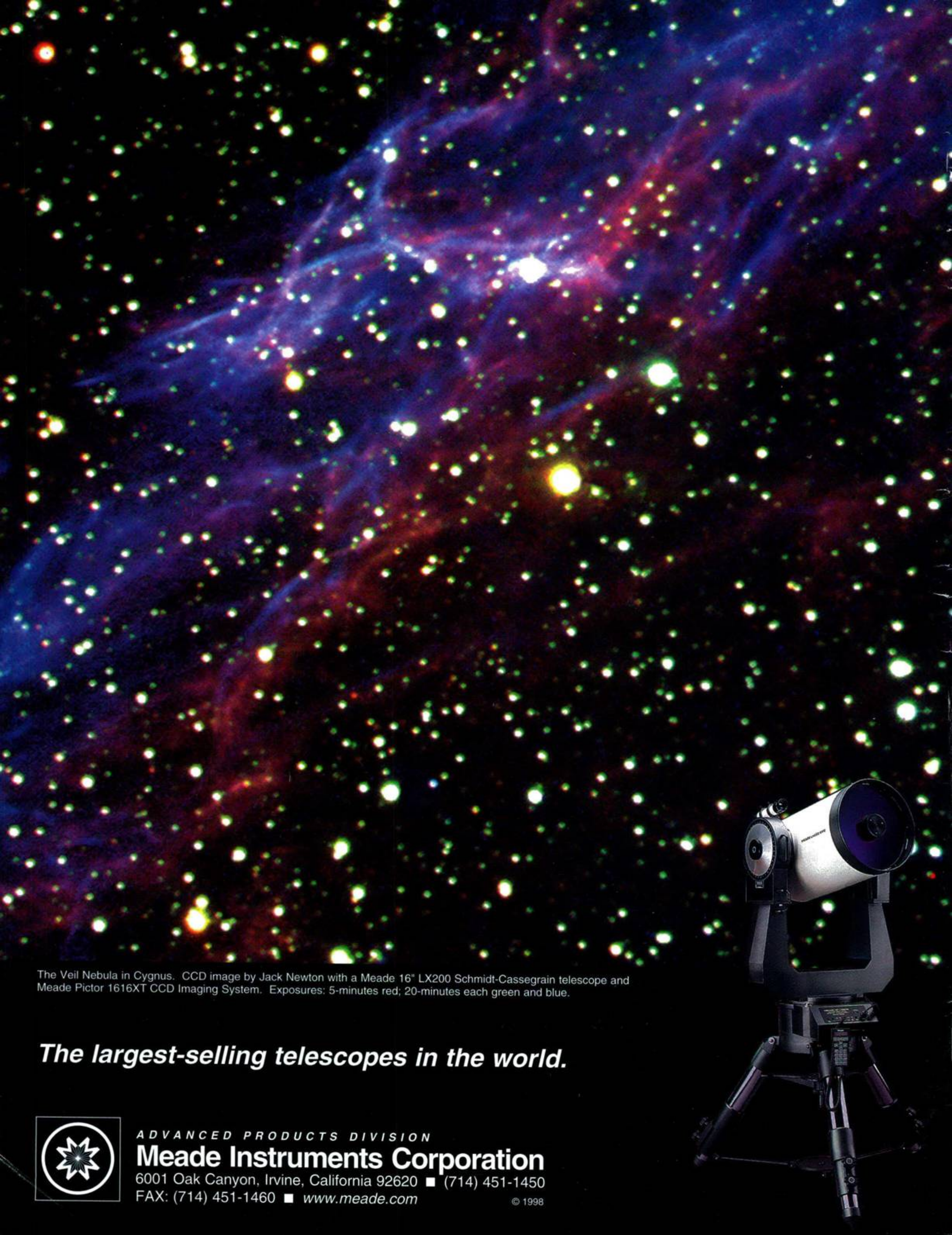

The Veil Nebula in Cygnus. CCD image by Jack Newton with a Meade 16" LX200 Schmidt-Cassegrain telescope and Meade Pictor 1616XT CCD Imaging System. Exposures: 5-minutes red; 20-minutes each green and blue.

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